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EVALUATION OF THE EFFECT OF COVID-19 ON COUNTRIES' SUSTAINABLE DEVELOPMENT LEVEL: A COMPARATIVE MCDM FRAMEWORK

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Abstract: *The extent of the outbreak of coronavirus disease (COVID-19) had a major impact on health, social life, economic and environmental activities in almost every country over the world. It has disrupted the sustainable development of countries and brought many uncertainties for their future capabilities. In this study, the effects of the COVID-19 on OECD countries' sustainable development were investigated, and the sustainable development performance of the countries was evaluated by the MultiAttributive Ideal-Real Comparative Analysis (MAIRCA) method. Data for the second quarter of 2020 and the same quarter of the previous year is considered. Then, the results obtained by the MAIRCA method were compared with two different multi-criteria decision-making (MCDM) methods called MABAC (Multi-Attributive Border Approximation Area Comparison) and WASPAS (Weighted Aggregated Sum Product Assessment). The effectiveness and validity of the results obtained from these methods were tested with Spearman's correlation coefficient. Finally, to examine the effect of COVID-19 on the indicators of sustainable development, a non-parametric Wilcoxon signed-rank test was applied. As a result, it was concluded that COVID-19 negatively affected the sustainable development of countries. However, sustainable development performances of developed countries have been observed to be better than developing countries.*

Keywords: *Pandemic, COVID-19, Sustainability, MAIRCA, Multi-Criteria Decision Making*

1. Introduction

In December 2019, Chinese Center for Disease Control and Prevention and Wuhan city health authorities reported an unknown pneumonia outbreak in Wuhan City, Hubei Province, China. On January 7, 2020, the center detected a new type of coronavirus that has never been seen in humans from the lower respiratory tract samples of patients (Wang et al., 2020; Li et al., 2020). Samples from the first patients

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were tested with many known pathogens. The new type of coronavirus showed similarity to respiratory diseases such as Severe Acute Respiratory Syndrome (SARS-CoV) and Middle East Respiratory Syndrome (MERS) (Lai et al., 2020). Symptoms of the new type of coronavirus include fever, cough, shortness of breath, and dyspnea. However, these symptoms differ from person to person. While most infected people develop mild to moderate symptoms, some patients experience severe pneumonia, pulmonary edema, and multiple organ failure, leading to death.

This infectious virus has been officially named as Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) by the World Health Organization (WHO). WHO used the term COVID-19 to describe the disease caused by the virus (WHO, 2020). This disease, the first case of which appeared in China in the last days of 2019, later began to occur in countries such as Japan, South Korea, and Thailand (Chen et al., 2020). The disease spread rapidly around the world in January 2020, and cases of virus began to be reported in several countries in Europe, North America, and Asia-Pacific (CDC, 2020; Hui et al., 2020; Bedford et al., 2020). On March 11, 2020, WHO declared COVID-19 as a global pandemic (WHO, 2020). At the time of writing this paper, the COVID-19 epidemic affected 213 countries and regions worldwide, infected more than 11 million 600 thousand people and the number of people who died globally has exceeded 530 thousand (COVID-19 Virus Pandemic, 2020). After WHO announced that the epicenter of the COVID-19 outbreak was Europe in the spring of 2020, the loss of life caused by COVID-19 increased in many countries, especially in Italy, France, Spain, and the United Kingdom. Again, at the time of writing this paper, it was announced by WHO that the new epicenter of COVID-19 was the continent of America and Asia. It was also reported that the pandemic risk continues largely; the USA, with more than 7 million cases, and India, with 6 million cases, have been the two countries in the world with the most COVID-19 cases. The number of deaths in both countries is increasing day by day and 200 thousand people in the USA and 96 thousand people in India died due to COVID-19 (Coronavirus Update, 2020). Although the COVID-19 pandemic was initially seen as a global health crisis, the situation has changed as the extent of the pandemic increased, and COVID-19 has become a deep political, economic, social, and environmental crisis in every country it touched. Due to the pandemic, in almost 90% of the world a wide range of social isolation and curfews have been implemented, many businesses have been closed, and domestic and international transportation services have been disrupted. Social restrictions and home isolation negatively affected many sectors especially production, health, transportation, tourism, real estate, education, energy, banking, etc. (Deloitte | Annual Turkish M&A Review, 2019). Even in the largest economies of the world, an economic contraction is foreseen that exceeds the estimates. According to International Monetary Fund (IMF) report titled "great isolation" dated April 14, 2020, the world is expected to experience the biggest global economic crisis since the "great depression" in 1929. In the report published by IMF, the growth expectation of the global economy has been revised as 3% shrinkage instead of 3.3% growth for 2020, and it is expected that global trade will decrease by 11% and oil prices by 42%. Due to the pandemic, a great decrease has occurred in the production and service sector and this made developing countries face high inflation and increasing unemployment. The gross domestic product, one of the most important economic indicators, fell by 1.8% in the OECD region in the first quarter of 2020 (World Economic Outlook, 2020).

However, it is not exactly known how dramatic the effects of the COVID-19 outbreak on the global economy will be. In The World Economic Forum report, it was stated that in addition to the economic problems, many countries would face many multidimensional problems in tourism, the housing market, demand for commercial products, transportation, unemployment, education, energy consumption, and impact on social life (World Economic Outlook, 2020). Tourism and service transportation is one of the sectors heavily hit by COVID-19. Transportation and transport activities have almost come to a halt during the quarantine process.

The World Travel and Tourism Council stated that 50 million jobs operating in the global tourism and travel industry are at risk (*News Article | World Travel & Tourism Council (WTTC)*, 2020). With the decrease in production in the pandemic period, the amount of energy needs to be decreased, as a result of which a decrease in energy production and investment was experienced. The positive aspect of the pandemic is that despite the decline in energy investments, renewable energy has resisted and continued to grow against the pandemic (IEA, 2020). Even though the disruption of the education process of children was prevented by initiating the distance / online education processes in the quarantine process, the discount / free meal application given in schools in many countries, which is especially important for disadvantaged people, was disrupted, and some of the students suspended their education as they could not connect to the internet, and this situation brought about socio-economic inequalities. As can be seen, the pandemic is a multidimensional global crisis that affects the economic, social, and environmental factors of the countries and disrupts its sustainable development. The United Nations (UN) stated that all the work done during and after this crisis should focus on building more resilient, equal, inclusive, and sustainable economies in the face of the challenges we face. Also, it was emphasized that the countries' recovery and sustainable development goals should be taken into consideration more than ever before to cope with the shocks that may be encountered in the pandemic in the future (UNDP, 2020).

Only a few studies have addressed the threat of the coronavirus pandemic to the sustainable development levels of countries. This paper attempts to investigate how the COVID-19 pandemic has changed the level of sustainable development for developed and less developed countries. Additionally, MCDM has become widely used in different sustainable development context over the past few years (Perez-Gladish et al., 2020). For this purpose, this study is to evaluate and compare the *level* of *sustainable development* of the OECD countries by using the MAIRCA model. MAIRCA is an effective MCDM method that takes into account the concept of the positive and negative ideal solution. The results obtained with the MAIRCA method were compared with new multi-criteria decision-making methods such as MABAC and WASPAS. The efficacy and validity of the results obtained in the three methods were tested with Spearman's correlation coefficient. Finally, the Wilcoxon signed-rank test was performed to examine the impact of COVID-19 on the indicators of sustainable development.

The rest of the paper is organized as follows: In Section 2, literature review on MAIRCA has presented. The steps of the MAIRCA method is explained in Section 3. Evaluation of the effect of COVID-19 on countries' sustainable development level based on the MAIRCA method is given in the fourth section. The results obtained to test the effectiveness and validity of MAIRCA method are illustrated in Section 5. Next section, the results of the Non-Parametric Wilcoxon signed-rank test are presented. Results and some limitations are discussed in detail in Section 7..

2. Literature review

MAIRCA is a popular method within the group of MCDM methods which is developed by Professor Dragan Pamucar in the Logistics Research Centre at the University of Defence in Belgrade (Pamucar et al., 2014). MAIRCA is easy to use in computation procedure and its calculation steps are similar to the ideal and non-ideal solution approach in the technique for order of preference by similarity to ideal solution (TOPSIS) method. (Gul and Ak, 2020).

The MAIRCA model is a considerable new decision-making method that can be very successfully combined with different MCDM methods. Related literature has been evaluated over the years. Gigović et al. (2016) aimed to determine the appropriate location for the ammunition depots by using the Geographic Information System (GIS) and MAIRCA methods together. To do this, the priority weights criteria of depots were determined by DEMATEL-ANP, and then the ranking of alternative regions was performed by MAIRCA. In the study by (Pamučar et al., 2017a), using a hybrid approach, the tenderers of the public procurement tender were evaluated by means of rough number based on DEMATEL, ANP, and MAIRCA methods. In another study, Pamucar et al. (2018) used the Full Consistency Method (FUCOM) and MAIRCA integrated methods in the location selection of level crossings to reduce the number of traffic accidents. Pamučar et al. (2019) defined six alternatives in determining the landing departure point of the vehicles in combat operations and they ranked their priorities with MAIRCA using interval-valued fuzzy-rough numbers. In their research, Badi and Ballem (2018) evaluated the supplier selection process by applying the integration of the rough numbers with the Best-Worst Method (BWM) and MAIRCA methods. As a result, it is determined that the cost, quality, and company profile are the three most important criteria. Chatterjee et al. (2018) evaluated the suppliers' performances considering the green supply chain criteria with the help of rough DEMATEL, Analytic Network Process (ANP) and MAIRCA methods. Pamucar et al. (2018) performed the location selection for a multi-model logistics facility that took into account sustainability criteria with the help of DEMATEL-MAIRCA methods. Based on the two main criteria that affect the ergonomic risk level, Ekinci and Can (2018) developed the CRITIC-MAIRCA method to achieve a combined risk level by taking into consideration the evaluation results made for the sub-criteria of these main criteria. Boral et al. (2020) listed the types of errors seen in the production facility of a small and medium-sized (SME) company operating in the automobile industry using the fuzzy MAIRCA method. Ulutaş (2019) used the Step-Wise Weight Assessment Ratio Analysis (SWARA) and MAIRCA integrated method in the selection of the catering company. Aycin (2020) used The criteria importance through intercriteria correlation (CRITIC) and MAIRCA methods in the selection of personnel to work in the IT department of a company operating in the logistics industry. Arsić et al. (2019) made a menu evaluation for a restaurant with BWM and rough MAIRCA methods. In the study by (Chatterjee et al., 2020), the MAIRCA method was used to evaluate the alternatives in lightweight environmentally friendly materials in the automotive industry. Pirbasti et al. (2020) selected the waste disposal facility location of eight hospitals using a hybrid approach with fuzzy SWARA and GIS-MAIRCA. In the study by

Pamučar and Savin (2020), BWM and MAIRCA methods were utilized together for the selection of military land vehicles, taking into account the 11 criteria defined. Gul and Ak (2020) used BWM and MAIRCA methods under fuzzy conditions to analyze potential risks in the marble factory. The relative importance of the three risk factors in the traditional Fine-Kinney method was calculated with fuzzy BWM, and the identified risks were ranked by fuzzy - MAIRCA.

3. MAIRCA method

MAIRCA, which has been added to MCDM literature by Gigovic et al., 2016, is a method based on defining the gaps between ideal and empirical ratings. By the addition of the gaps for each criterion, the total gap for decision alternatives is obtained. At the end of the application process, the alternative that is the closest to the ideal ratings according to most of the criteria, or in other words, the alternative with the lowest total gap value is determined as the best alternative (Gigović et al., 2016; Pamučar et al., 2017). The MAIRCA method has an implementation process consisting of eight steps (Pamucar et al., 2018).

Step 1: Creating the Initial Decision Matrix (X): The criteria(C_j) values obtained from each alternative (A_i) are shown in Equation (1).

$$X = \begin{array}{c} \begin{matrix} C_1 & C_2 & \cdots & C_n \end{matrix} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \end{array} \tag{0}$$

Step 2: Determining the Priorities of Alternatives: The absence of a priority in the alternative selection process of the decision-maker is an assumption of the method, *m* as the total number of alternatives, *i*. The priority of the alternative Pr_{Ai} is calculated as shown in Equation (2).

$$Pr_{Ai} = \frac{1}{m}; \qquad \sum_{i=1}^{m} Pr_{Ai} = 1 \qquad i = 1, 2, \dots, m \tag{2}$$

The decision-maker is equidistant to any alternative. Therefore, all priorities are equal, as shown in Equation (3).

$$Pr_{A1} = Pr_{A2} = \cdots = Pr_{Am} \tag{3}$$

Stage 3: Construction of the Theoretical Rating Matrix (T_p): The elements of the matrix (t_{pij}) are calculated by multiplying the priorities of alternatives (Pr_{Ai}) and the criterion weights (w_j), as shown in Equation (4).

$$\boldsymbol{T_p} = \begin{bmatrix} \mathrm{Pr_{A1}.w_1} & \mathrm{Pr_{A1}.w_2} & \dots & \mathrm{Pr_{A1}.w_n} \\ \mathrm{Pr_{A2}.w_1} & \mathrm{Pr_{A2}.w_2} & \dots & \mathrm{P_{rA2}.w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \mathrm{Pr_{Am}.w_1} & \mathrm{Pr_{Am}.w_2} & \dots & \mathrm{Pr_{Am}.w_n} \end{bmatrix} \tag{4}$$

Stage 4: Defining the Real Rating Matrix $(\boldsymbol{T_r})$***:*** In order to obtain T_r matrix, theoretical grading matrix T_p and initial decision matrix X are used. Matrix elements should be calculated by using Equation (5) for maximization criteria and Equation (6) for minimization criteria.

$$\mathrm{t_{rij}} = \mathrm{t_{pij}} \ . \ \left(\frac{\mathrm{x_{ij}} - \mathrm{x_{ij}^-}}{\mathrm{x_{ij}^+} - \mathrm{x_{ij}^-}}\right) \tag{5}$$

$$\mathrm{t_{rij}} = \mathrm{t_{pij}} \ . \ \left(\frac{\mathrm{x_{ij}} - \mathrm{x_{ij}^+}}{\mathrm{x_{ij}^-} - \mathrm{x_{ij}^+}}\right) \tag{6}$$

x_{ij}^+ is the highest value of the criterion from the alternative $(x_{ij}^+ = \max(x_1, x_2, \dots, x_m))$, x_{ij}^- is the lowest value of the criterion from the alternative $(x_{ij}^- = \min(x_1, x_2, \dots, x_m))$.

The actual rating matrix to be obtained as a result of calculations is shown in Eq. (7).

$$\begin{matrix} & C_1 & C_2 & \dots & C_n \end{matrix}$$
$$T_r = \begin{bmatrix} \mathrm{t_{r11}} & \mathrm{t_{r12}} & \dots & \mathrm{t_{r1n}} \\ \mathrm{t_{r21}} & \mathrm{t_{r22}} & \dots & \mathrm{t_{r2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \mathrm{t_{rm1}} & \mathrm{t_{rm2}} & \dots & \mathrm{t_{rmn}} \end{bmatrix} \tag{7}$$

Stage 5: Computation of Total Gap Matrix (G)

With the help of Gap Matrix (G), Equation (8), the difference between the theoretical rating matrix (T_p) and the actual grading matrix (T_r) is obtained as shown in Eq. (9).

$$g_{ij} = t_{pij} - t_{rij} \qquad g_{ij} \in [0, \infty) \tag{8}$$

$$G = T_p - T_r = \begin{bmatrix} g_{11} & g_{12} & \cdots & g_{1n} \\ g_{21} & g_{22} & \cdots & g_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ g_{m1} & g_{m2} & \cdots & g_{mn} \end{bmatrix} \tag{9}$$

Stage 6: Determining the Total Gap with Alternatives

If theoretical rating (t_{pij}) and real rating (t_{rij}) of an alternative (A_i) for a criterion (C_j) are equal and different from zero, the gap will be zero $(g_{ij} = 0)$. In this case, this alternative (A_i) would be the ideal alternative (A_i^+) for this criterion (C_j). If the theoretical rating (t_{pij}) of an alternative (A_i) for a criterion (C_j) equals zero $(t_{pij} = t_{rij} = g_{ij} = 0)$, then the gap for the alternative (A_i) for the criterion (C_j) is $(g_{ij} = 0)$. In this case, this alternative (A_i) will be the worst alternative (A_i^-) for this criterion (C_j).

Stage 7: Calculation of the Value (Q_i) of the Final Criteria Functions of Alternatives

The value of the criteria functions is calculated to take advantage of Equation (10) for each alternative.

$$Q_i = \sum_{j=1}^{n} g_{ij} \quad , \quad i = 1, 2, \dots , m \tag{10}$$

Q_i values are ranked from small to a large value, and alternatives are obtained.

4. Evaluate the effects of the COVID-19 pandemic on sustainable development performance of OECD countries

The Organization for Economic Co-operation and Development, or OECD in short, is an international platform that works jointly to solve the economic, social, and management problems of member countries. This establishment was founded in Paris in 1961 and was originally established with 20 countries. Later, the number of OECD member countries increased to 37 with the participation in developmentally and socioeconomically different countries (Our global reach - OECD, 2020). The main purpose of OECD is to support countries in ensuring sustainable economic growth, increasing employment, raising living standards, ensuring economic stability and contributing to the growth of world trade. Member states of the organization constitute 63 percent of GDP, three-quarters of world trade, 95 percent of world official development aid and more than half of world energy consumption in today's world (What is OECD, 2020).

In the study, Colombia, Luxemburg, Israel and New Zealand were excluded from this study due to the unavailability of some data for this method. The impact of COVID-19 on the sustainable development performances of a total of 33 OECD countries were analyzed using MAIRCA considering the data of the second quarter (Q2) of 2020 and the data of the same quarter of the previous year (2019). To test the validity and effectiveness of this method, the ranking results of MAIRCA were compared with the results obtained from novel MCDM models such as MABAC and WASPAS. Additionally, the Wilcoxon signed-rank test is conducted to determine whether the sustainable development indicators of OECD countries differ between the Q2/2019 and Q2/2020. The general framework of this study is summarized in Figure 1.

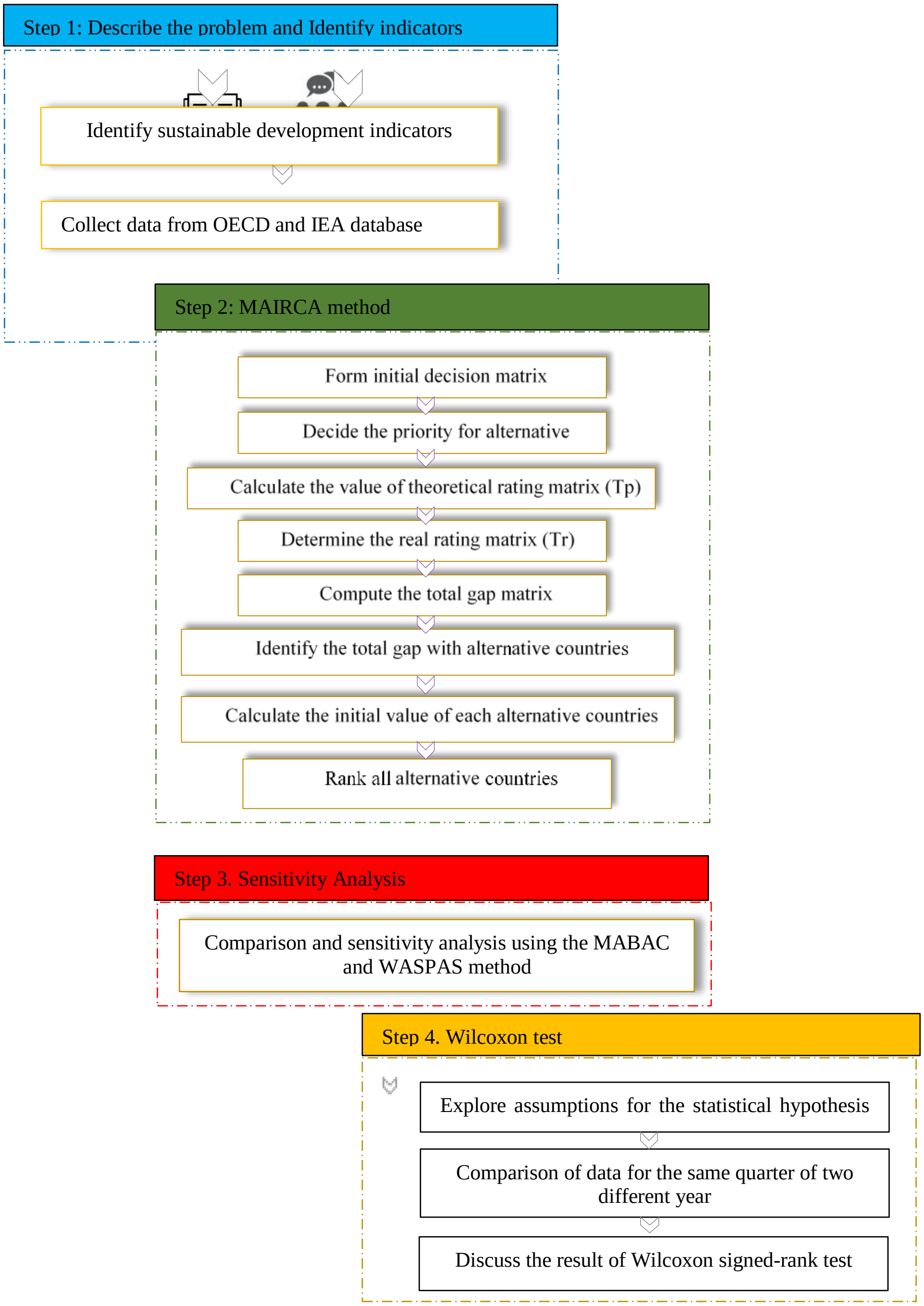

Figure 1. General framework of study

Sustainable development indicators of OECD countries have been determined in line with the sustainable development goals of OECD, the European Union, and the United Nations and literature review. In addition, all the indicators used in this study were designed to take into account all dimensions, namely the economy, environment, and social, which constitute the sustainable development model. Eight different sustainable development indicators comprising Total Electricity Production, Renewable Energy Production, Merchandise Trade, Customer Price Index (CPI), Analytical House Price Indicators (rent price), Gross Domestic Product (GDP), Producer Price Index (PPI), unemployment rate, aged 15 and over were selected in this study. The indicators were analyzed for their ability to measure the economic, environmental and social dimensions of sustainable development. Data on economic and social indicators (I3, I4, I5, I6, I7, I8) were obtained from the OECD databases, and environmental indicators (I1 and I2) were obtained from reports published by the International Energy Agency (IEA). Definitions, indices, and periods considered in the study regarding indicators of sustainable development are shown in Table 1.

Table 1. Indicators of sustainable development

Not.	Indicator	Unit	Quarter / Year	References
I1	Total Electricity Production	GWh	Q2/2019 - Q2/2020	(Ding et al., 2016); (Sustainable Development Goals, 2020)
I2	Renewable Energy production	GWh	Q2/2019 - Q2/2020	(Mateusz et al., 2018); (Kothari et al., 2010); (Sustainable Development Goals, 2020); (Sathaye et al., 2011)
I3	Merchandise Trade	US Dollar, Billions	Q2/2019 - Q2/2020	(Ding et al., 2016); (Sustainable Development Goals, 2020)
I4	Customer price index	Index, 2015=100	Q2/2019 - Q2/2020	(Gaspar et al., 2017); (Sustainable Development Goals, 2020)
I5	Analytical House Rent Price indicators	Index	Q2/2019 - Q2/2020	(Zavadskas et al., 2017); (Sustainable Development Goals, 2020)
I6	Gross Domestic Product	Annual growth rate (%)	Q2/2019 - Q2/2020	(Bali Swain and Yang-Wallentin, 2020); (Balcerzak and Pietrzak, 2016); (Ding et al., 2016): (Gaspar et al., 2017); (Sustainable Development Goals, 2020)
I7	Producer price index	Index, 2015=100	Q2/2019 - Q2/2020	(Sustainable Development Goals, 2020)
I8	The unemployment rate, aged 15 and over	%	Q2/2019 - Q2/2020	(Bali Swain and Yang-Wallentin, 2020); (Balcerzak and Pietrzak, 2016); (Ding et al., 2016); (Mateusz et al., 2018); (Gaspar et al., 2017)

Total Electricity Production (I1): Electricity generated different type of energy resources such as fossil fuels, nuclear power plants, hydropower plants (excluding pumped storage), geothermal systems, solar panels, biofuels, wind, etc.

Renewable Energy production (I2): Renewable Energy is the energy received from the energy flow that exists in the natural processes that continue continuously. They are hydro energy, wind, solar, geothermal, and other renewable energy sources.

Merchandise Trade (I3): Goods that add or subtract from the stock of material resources of a country by entering (imports) or leaving (exports) its economic territory.

Customer price index (I4): Defined as the change in the prices of a basket of goods and services that are typically purchased by specific groups of households.

Analytical House Rent Price indicators (I5): House price indices (rent prices), are index numbers that measure the rent prices of residential properties over time.

Gross Domestic Product (I6): The standard measure of the value-added created through the production of goods and services in a country during a certain period.

Producer price index (I7): The rate of change in the prices of products sold as they leave the producer.

The unemployment rate, aged 15 and over (I8): The number of unemployed people as a percentage of the labor force, where the latter consists of the unemployed plus those in paid or self-employment.

Table 2. Initial decision matrix

	Indicators							
Countries	I1	I2	I3	I4	I5	I6	I7	I8
Australia	21041	4304	69.61	106.6	102.5	1223934.95	111.1	5.231
Austria	6357	5842	44.75	106.7	114.4	469791.799	105.1	4.500
Belgium	6891	1376	112.24	107.9	103.9	553085.807	113.5	5.467
Canada	47322	31979	114.90	107.7	104.6	1723905.35	106.4	5.567
Chile	6804	2560	17.06	111.1	117.8	445180.531	108.8	6.980
Czech Republic	6613	925	50.17	108.1	109.7	406561.381	103.0	1.967
Denmark	2292	1955	27.84	103.1	104.9	308065.246	105.9	4.933
Estonia	489	137	4.11	109.9	130.7	45784.7699	109.7	4.867
Finland	5202	2999	18.65	103.4	108.2	254103.301	104.7	6.800
France	44439	9888	145.44	104.4	100.6	2908013.64	103.3	8.500
Germany	45887	20169	371.46	105.5	105.4	4150471.67	105.4	3.067
Greece	3117	1227	9.66	101.9	92.1	306790.238	104.7	17.333
Hungary	2258	358	30.36	109.4	123.4	307584.948	115.0	3.433
Iceland	1660	1660	1.28	109.4	120.0	18920.8022	99.0	3.367
Ireland	2293	625	42.61	102.1	115.9	413134.441	100.6	5.200
Italy	22141	10296	133.67	103.0	101.0	2335523.24	103.5	10.000
Japan	73035	36284	181.29	101.7	99.3	5356221.8	101.0	2.367
Korea	43570	3031	136.20	104.9	104.0	2150833.19	102.7	4.000
Latvia	402	244	3.94	109.4	107.0	55221.0561	110.5	6.367
Lithuania	282	206	8.41	110.4	126.0	96063.1159	107.2	6.100
Mexico	27884	5347	117.21	117.9	110.0	2388177.33	126.3	3.549
Netherlands	9374	1796	176.64	106.0	108.2	930705.86	109.4	3.333
Norway	9770	9502	26.31	110.6	107.6	331933.394	114.0	3.433
Poland	12052	1848	66.00	105.7	112.8	1204174.54	109.7	3.333
Portugal	4037	2176	16.89	104.2	107.5	339634.903	104.8	6.600
Slovak Republic	2264	695	22.21	106.0	101.3	181242.251	103.7	5.767
Slovenia	1419	588	11.31	105.4	118.4	75067.7421	103.1	4.367
Spain	20784	8803	84.80	104.6	103.0	1790431.14	105.3	14.200
Sweden	12703	7655	40.11	106.8	104.1	519697.892	112.1	6.533
Switzerland	5744	3551	61.12	102.0	102.1	569152.648	100.4	4.455
Turkey	23989	14407	44.52	158.2	141.4	2330974.19	186.2	13.867
United Kingdom	23914	8185	108.49	107.8	103.8	2948323.99	111.5	3.767
United States	332986	74378	408.63	108.0	115.3	19900185.1	106.94	3.633
AIM	MAX	MAX	MAX	MIN	MIN	MIN	MIN	MIN

In this study, one of the expert is an engineer with expertise in Regional development at the Ankara Development Agency in Turkey, and the others are two academics working in the economics and business department of the university. In line with the opinion received from three experts, as a result of interview with experts, the sustainable indicator should equal the importance weight. In the application of the MAIRCA method, data of 33 OECD countries are obtained from the OECD and IEA databases. The initial decision matrix for the second quarter of 2020 and the aim of each indicator are presented in Table 2.

Due to the nature of the method, the decision-maker should not have a priority in the choice of an alternative. Since there are 33 alternative countries (n), the priority (Pr_{Ai}) of each alternative is calculated as shown in Equation 2.

$$Pr_{Ai} = \frac{1}{n} = \frac{1}{33} = 0.030 \tag{11}$$

$$Pr_{A1} = Pr_{A2} = Pr_{A3} = Pr_{A4} = \ldots\ldots\ldots\ldots\ldots = Pr_{A33} = 0.030 \tag{12}$$

The theoretical rating matrix was calculated by Eq. (3) and Eq. (4), respectively. Matrix elements are obtained by multiplying the chosen alternative preferences (Pr_{Ai}) and the coefficients (w_i) of the weights of the indicators. Experts assumed that the indicator weights were of equal coefficient. The theoretical rating matrix (T_p) is shown in Table A1 (Appendix). After this matrix was calculated, the real evaluation matrix (T_r) was created, as given in Table A2 (Appendix). The actual evaluation matrix element is found by multiplying the theoretical rating matrix element with the normalized start matrix element. The normalized initial matrix was calculated using the Eq. (6) and Eq. (7). The total gap matrix (G) was obtained by subtracting the real rating matrix (t_{rij}) from the theoretical rating matrix (t_{pij}), as shown in Eq. (8) and Eq. (9).

It is preferred that the gap value be close to zero. The gap matrix is shown in Table A3 in Annex. In the last step of the method, by using the total gap matrix in Table A3 (Appendix), the criterion function values of decision alternatives were calculated by using Equation (10). The function values (Q_i) of the criteria obtained for the second quarter of 2019 with the MAIRCA method and the ranking of the OECD countries are shown in Table 3.

Similar steps were followed using data from the second quarter of 2020, when COVID-19 started to spread worldwide, and the ranking of the sustainability performances of OECD countries obtained by MAIRCA method for the second quarter of 2019 and 2020 is shown in Figure 1.

According to the results given in Table 3, the country with the best sustainability performance among OECD countries is the United States. This country is followed by Japan, Germany, Canada, Korea, and the Netherlands, respectively.

Table 3. The ranking of OECD countries using the MAIRCA method (Q2/2020)

Countries	Qi	Rank	Countries	Qi	Rank
United States	0.0090	1	Slovak Republic	0.0136	18
Germany	0.0091	2	Austria	0.0137	19
Japan	0.0095	3	Portugal	0.0138	20
Korea	0.0114	4	Finland	0.0138	21
Netherlands	0.0117	5	Sweden	0.0139	22
France	0.0119	6	Slovenia	0.0139	23
Switzerland	0.0121	7	Latvia	0.0146	24
United Kingdom	0.0123	8	Iceland	0.0146	25
Italy	0.0123	9	Mexico	0.0147	26
Belgium	0.0127	10	Spain	0.0148	27
Canada	0.0129	11	Hungary	0.0148	28
Czech Republic	0.0130	12	Greece	0.0150	29
Australia	0.0131	13	Estonia	0.0153	30
Denmark	0.0133	14	Lithuania	0.0157	31
Ireland	0.0133	15	Chile	0.0166	32
Norway	0.0135	16	Turkey	0.0249	33
Poland	0.0135	17			

The sustainability performance rankings of the countries in the second quarter of 2020, in which the COVID-19 pandemic spread worldwide, were compared in the same period of the previous year, as shown in Figure 2. According to the results obtained with MAIRCA in the second quarter of 2020, the USA belongs to the best sustainable development level among alternative countries. This country is followed by Germany, Japan, Korea and the Netherlands, respectively. Countries with the worst sustainable development performance of the same period, the lowest ranking countries in terms of sustainability performance, are Turkey (33rd), Chile (32nd), Lithuania (31st), Estonia (30th), and Greece (29th). To examine how the COVID-19 pandemic has affected the sustainable development goals of OECD countries, data from the same period of the previous year were used and the MAIRCA method was resolved again. The comparison of the sustainable performance levels for both quarters is shown in Figure 2. Accordingly, the country with the highest sustainable development performance in April-May-June 2019 was America, followed by Japan, Germany, Canada and Korea, respectively. In the ranking results, Canada ranked 4th in 2019, ranked 11th during the pandemic period. The pandemic has been shown to seriously affect Canada's level of sustainable development. It can be seen that for Hungary, Turkey, Greece, Lithuania, Australia, Denmark, Norway, Poland, Sweden, in terms of development sustainability, rankings are stable.

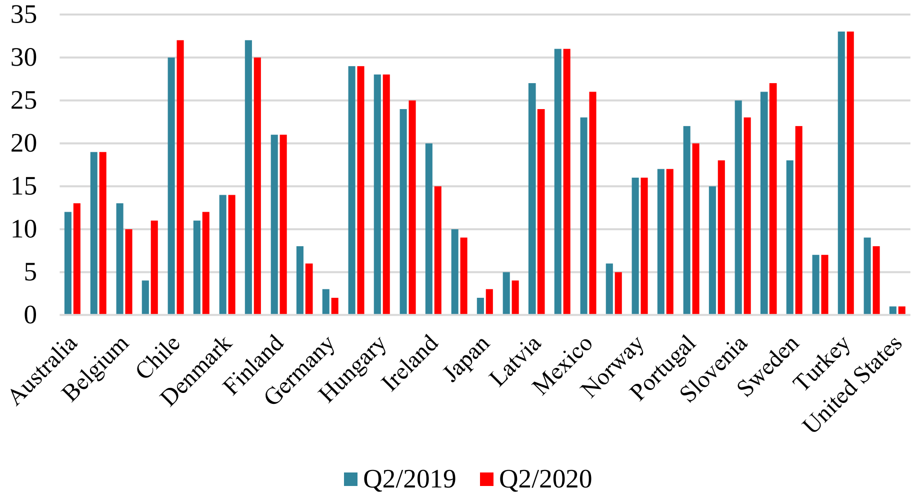

Figure. 2. Comparison of sustainability performance rankings (Q2/2019-Q2/2020)

5. Sensitivity Analysis

The reliability of the results obtained from the MAIRCA model should be tested to ensure the validity of the selected alternatives. For this purpose, the reliability and validity of the model were analyzed by using the MABAC method and WASPAS method. Results obtained with MAIRCA, MABAC and WASPAS methods are quite similar to each other. A comparison of results obtained using three MCDM methods are illustrated in Figure 3 and Figure 4, respectively. As can be seen from Figure 3, in all three methods, the United States has the best sustainable development performance. In the second quarter of 2019, Japan, Germany, Canada and Korea have the same rank in all three methods.

The Spearman correlation coefficient was used to determine the relationships between these methods. The Spearman correlation coefficient is used to measure the similarity between two group rankings. This method with a higher Spearman's rank relationship coefficient is accepted to be more significant than one with a lower Spearman's rank connection coefficient since it has better concurrences with other MCDM methods (Gang Kou, Yanqun Lu, Yi Peng, & Yong Shi, 2012). Spearman correlation coefficients for both years are shown in Table 4. According to the validity results, the correlation coefficient is above 87.2% and it has a high correlation. This confirms that the MAIRCA method is in agreement with other MCDM methods and its results are reliable.

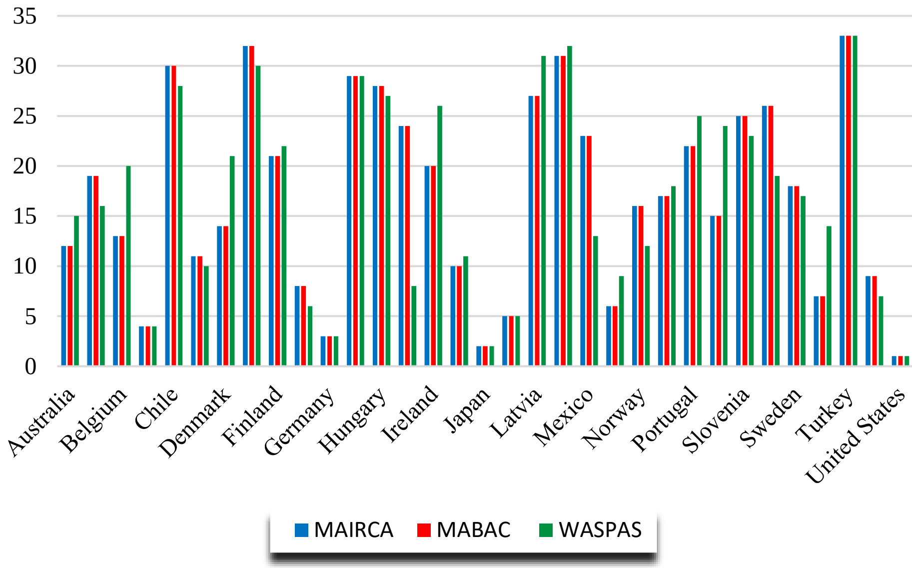

Figure 3. The ranking of OECD countries (Q2/2019)

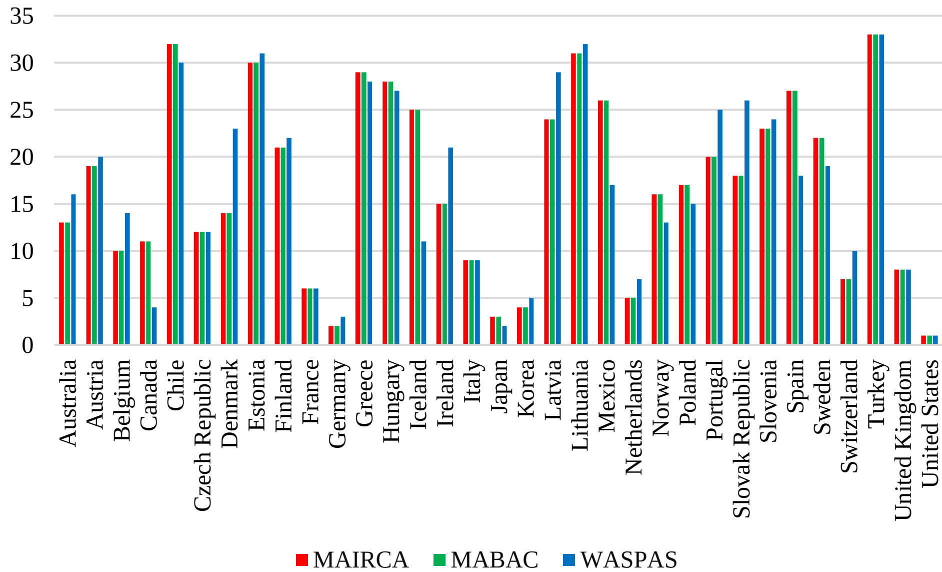

Figure 4. The ranking of OECD countries (Q2/2020)

Table 4. Correlation values of methods

Spearman's coefficient	MABAC	WASPAS	Average value
MAIRCA (Q2/2019)	1.000	0.872	0.936
MAIRCA (Q2/2020)	0.644	0.881	0.762

6. Wilcoxon Signed-Rank Test

The Non-Parametric Wilcoxon signed-rank test was applied to determine whether there is a significant difference between the second quarter of 2020 and the same quarter of the previous year in terms of the indicators of the sustainable development of OECD countries. It can be clearly seen in Table 5, *p* values of all indicators are less than 0.05 value. According to Wilcoxon test hypothesis, if *p*-value is less than zero, the null hypothesis is rejected and it is concluded that there is a significant difference between the period (April-June 2019) and (April-June 2020). Accordingly, Table 5 shows that as the *p* values of "Total Electricity Production (I1), Renewable Energy Production (I2), Merchandise Trade (I3), Customer Price Index (I4), Analytical house rent price indicators (I5), GDP (I6)", Producer Price Index (I7), Unemployment rate, aged 15 and over (I8) are less than 0.05, results demonstrated that there are differences between before and during the COVID-19 pandemic. Test results are clearly expressed in Table 5 and 6, respectively.

Table 5. Wilcoxon signed-rank test results

	I1(2020)- I1(2019)	I2(2020) - I2(2019)	I3(2020) - I3(2019)	I4(2020)- I4(2019)	I5(2020)- I5(2019)	I6(2020- I6(2019)	I7(2020)- I7(2019)	I8(2020)- I8(2019)
Z	-3.815[b]	-2.10[b]	-5.012[b]	-2.124[c]	-3.293[c]	-5.012[b]	-3.475[c]	-3.726[c]
p	0.000	0.036	0.000	0.034	0.001	0.000	0.001	0.000

a. Wilcoxon Signed-Rank Test, b. Based on positive ranks, c. Based on negative ranks

As seen in Table 6, the total electricity production of 26 OECD countries decreased in the second quarter of 2020. It is observed that the COVID-19 pandemic has negatively affected the energy production of OECD countries. However, this situation has changed in the amount of renewable energy generation. In the second quarter of 2020, which was heavily affected by the pandemic, the amount of renewable energy production of 22 countries increased compared to the second quarter of the previous year. It is interesting to note that COVID-19 pandemic has a positive effect on renewable energy goals. The global COVID-19 novel coronavirus pandemic has severe negative impacts on the global economy. GDP is an important indicator to bring coherence to the sustainable development goals. When the result on house rent prices were analyzed, the consumer price index of 27 countries increased compared to the second quarter of 2019. According to Table 6, Merchandise trade and GDP of all OECD countries plunged in the second quarter of 2020 as compared to the same period last year. The COVID-19 has prevented countries from achieving their sustainable development goals.

The producer price index means the average change over time in selling prices received by domestic producers of goods and services. The producer price index of 29 countries decreased compared to the same quarter of the previous year. The other important sustainable development indicator is the unemployment rate; the test result indicates that the unemployment rate of 26 countries has increased compared to the same period of the previous year. Coronavirus has hit unemployment in OECD countries. The results found that all sustainable development indicators, except renewable energy production, have been severely affected by the COVID-19 pandemic.

Table 6. Cash Ratio Ranks

		Number	*Mean Rank*	*Sum of Ranks*
I1 (2019) – I1(2020)	Negative Ranks	26	19.00	494.0
Total Electricity production	Positive Ranks	7	9.57	67.0
I2 (2019) – I1(2020)	Negative Ranks	11	14.82	163.0
Renewable energy	Positive Ranks	22	18.09	398.0
I3 (2019) – I1(2020)	Negative Ranks	33	17.00	561.0
Merchandise trade	Positive Ranks	0	0.00	0
I4 (2019) – I1(2020)	Negative Ranks	12	12.54	150.5
CPI	Positive Ranks	20	18.88	377.5
I5 (2019) – I1(2020)	Negative Ranks	4	20.00	80.0
Rent price	Positive Ranks	27	15.41	416.0
I6 (2019) – I1(2020)	Negative Ranks	33	17.00	561.0
GDP	Positive Ranks	0	0.00	0.0
I7 (2019) – I1(2020)	Negative Ranks	29	17.59	475.0
Producer price index	Positive Ranks	6	14.33	86.0
I8 (2019) – I1(2020)	Negative Ranks	7	10.29	72.0
Unemployment rate				
	Positive Ranks	26	18.81	489.0

7. Results and Limitations

World economies have faced serious health problems and socio-economic crises due to the COVID-19 pandemic. The COVID-19 pandemic continues to threaten life, to suppress the world economy, and to have a profound impact on social and environmental issues. National and international community organizations emphasized that countries should pay more attention to sustainable development goals in the post-COVID-19 recovery phase in order to reduce the destructive effect of the COVID-19 crisis.

In this study, the effect of the COVID-19 pandemic on the sustainable development of OECD countries was investigated with a novel MCDM method. For this purpose, the MAIRCA method was used to rank the sustainability performance of OECD countries and test its validity and reliability with MABAC and WASPAS methods. Moreover, statistical analysis was implemented and obtained results were discussed in view of sustainable development.

The analysis leads to the following conclusions: United States, Germany, Japan, France, and South Korea are with the best development performance while countries with the worst performance are Turkey, Chile, Lithuania, and Estonia for the same quarter of 2019 and 2020. Developed countries are in the top position in the ranking of sustainable development performance compared to developing countries, and this situation did not change with the appearance of the COVID-19 pandemic; the rankings score was the same. In order to test the validity and effectiveness of the MAIRCA method, the ranking results of MAIRCA were compared with the results obtained from novel MCDM models such as MABAC and WASPAS. It has been observed that all MCDM methods used give effective results to determine the ranking of countries under a sustainable development level. Furthermore, a Non-parametric Wilcoxon Signed-Rank test was used to determine whether the direction of changes of each sustainable development indicator was different between the pre-COVID-19 and COVID-19.

Accordingly, results demonstrated that there were significant differences between before and during the COVID-19 pandemic. Importantly, our results provide evidence that, except for renewable energy production, all sustainable indicators have adversely been affected by the COVID-19 pandemic. However, this study has revealed that COVID 19 has had an innovator effect by changing the direction of energy production resources. The pandemic has tripped the scale in favor of renewable energy.

There are a number of limitations for this study. One of the main limitations is the missing dataset. Due to the continuing COVID-19 pandemic, there are missing and uncompleted sustainable development indicators such as the "number of hospital beds", "attendance at school", "inequality in education", "life expectancy", "gender inequality", etc. Further study will reevaluate with a different type of sustainable indicators. Another limitation of the study is that it only takes into account the impact of the pandemic on OECD countries' sustainable development performances. In the future study, new research is planned with different countries included in OPEC, G20, and BRIC countries.

Appendix

Table A1. Theoretical Evaluation Matrix (Tp)

Countries	I1	I2	I3	I4	I5	I6	I7	I8
Australia	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Austria	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Belgium	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Canada	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Chile	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Czech Republic	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Denmark	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Estonia	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Finland	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
France	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Germany	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Greece	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Hungary	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Iceland	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Ireland	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Italy	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Japan	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Korea	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Latvia	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Lithuania	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Mexico	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Netherlands	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Norway	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Poland	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Portugal	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Slovak Republic	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Slovenia	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Spain	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Sweden	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038

Switzerland	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
Turkey	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
United Kingdom	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
United States	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038

Table A2. Real Evaluation Matrix (Tr)

Countries	I1	I2	I3	I4	I5	I6	I7	I8
Australia	0.0002	0.0002	0.0006	0.0035	0.0030	0.0036	0.0033	0.0030
Austria	0.0001	0.0003	0.0004	0.0035	0.0021	0.0037	0.0035	0.0032
Belgium	0.0001	0.0001	0.0010	0.0034	0.0029	0.0037	0.0032	0.0029
Canada	0.0005	0.0016	0.0011	0.0034	0.0028	0.0035	0.0035	0.0029
Chile	0.0001	0.0001	0.0001	0.0032	0.0018	0.0037	0.0034	0.0026
Czech Republic	0.0001	0.0000	0.0005	0.0034	0.0024	0.0037	0.0036	0.0038
Denmark	0.0000	0.0001	0.0002	0.0037	0.0028	0.0037	0.0035	0.0031
Estonia	0.0000	0.0000	0.0000	0.0032	0.0008	0.0038	0.0033	0.0031
Finland	0.0001	0.0001	0.0002	0.0037	0.0025	0.0037	0.0035	0.0026
France	0.0005	0.0005	0.0013	0.0036	0.0031	0.0032	0.0036	0.0022
Germany	0.0005	0.0010	0.0034	0.0035	0.0028	0.0030	0.0035	0.0035
Greece	0.0000	0.0001	0.0001	0.0038	0.0038	0.0037	0.0035	0.0000
Hungary	0.0000	0.0000	0.0003	0.0033	0.0014	0.0037	0.0031	0.0034
Iceland	0.0000	0.0001	0.0000	0.0033	0.0016	0.0038	0.0038	0.0034
Ireland	0.0000	0.0000	0.0004	0.0038	0.0020	0.0037	0.0037	0.0030
Italy	0.0002	0.0005	0.0012	0.0037	0.0031	0.0033	0.0036	0.0018
Japan	0.0008	0.0018	0.0017	0.0038	0.0032	0.0028	0.0037	0.0037
Korea	0.0005	0.0001	0.0013	0.0036	0.0029	0.0034	0.0036	0.0033
Latvia	0.0000	0.0000	0.0000	0.0033	0.0026	0.0038	0.0033	0.0027
Lithuania	0.0000	0.0000	0.0001	0.0032	0.0012	0.0038	0.0034	0.0028
Mexico	0.0003	0.0003	0.0011	0.0027	0.0024	0.0033	0.0026	0.0034
Netherlands	0.0001	0.0001	0.0016	0.0035	0.0026	0.0036	0.0033	0.0035
Norway	0.0001	0.0005	0.0002	0.0032	0.0026	0.0037	0.0031	0.0034
Poland	0.0001	0.0001	0.0006	0.0035	0.0022	0.0036	0.0033	0.0035
Portugal	0.0000	0.0001	0.0001	0.0036	0.0026	0.0037	0.0035	0.0026
Slovak Republic	0.0000	0.0000	0.0002	0.0035	0.0031	0.0038	0.0036	0.0029
Slovenia	0.0000	0.0000	0.0001	0.0035	0.0018	0.0038	0.0036	0.0032
Spain	0.0002	0.0004	0.0008	0.0036	0.0030	0.0035	0.0035	0.0008
Sweden	0.0001	0.0004	0.0004	0.0035	0.0029	0.0037	0.0032	0.0027
Switzerland	0.0001	0.0002	0.0006	0.0038	0.0030	0.0037	0.0037	0.0032
Turkey	0.0003	0.0007	0.0004	0.0000	0.0000	0.0033	0.0000	0.0009
United Kingdom	0.0003	0.0004	0.0010	0.0034	0.0029	0.0032	0.0032	0.0033
United States	0.0038	0.0038	0.0038	0.0034	0.0020	0.0000	0.0034	0.0034

Table A3. Total Gap Matrix

Countries	I1	I2	I3	I4	I5	I6	I7	I8
Australia	0.0036	0.0036	0.0032	0.0003	0.0008	0.0002	0.0005	0.0008
Austria	0.0037	0.0035	0.0034	0.0003	0.0017	0.0001	0.0003	0.0006
Belgium	0.0037	0.0037	0.0028	0.0004	0.0009	0.0001	0.0006	0.0009
Canada	0.0033	0.0022	0.0027	0.0004	0.0010	0.0003	0.0003	0.0009
Chile	0.0037	0.0037	0.0036	0.0006	0.0020	0.0001	0.0004	0.0012
Czech Republic	0.0037	0.0037	0.0033	0.0004	0.0014	0.0001	0.0002	0.0000
Denmark	0.0038	0.0037	0.0035	0.0001	0.0010	0.0001	0.0003	0.0007
Estonia	0.0038	0.0038	0.0038	0.0005	0.0030	0.0000	0.0005	0.0007
Finland	0.0037	0.0036	0.0036	0.0001	0.0012	0.0000	0.0002	0.0012

France	0.0033	0.0033	0.0024	0.0002	0.0007	0.0006	0.0002	0.0016
Germany	0.0033	0.0028	0.0003	0.0002	0.0010	0.0008	0.0003	0.0003
Greece	0.0038	0.0037	0.0037	0.0000	0.0000	0.0001	0.0002	0.0038
Hungary	0.0038	0.0038	0.0035	0.0005	0.0024	0.0001	0.0007	0.0004
Iceland	0.0038	0.0037	0.0038	0.0005	0.0021	0.0000	0.0000	0.0003
Ireland	0.0038	0.0038	0.0034	0.0000	0.0018	0.0001	0.0001	0.0008
Italy	0.0035	0.0033	0.0026	0.0001	0.0007	0.0004	0.0002	0.0020
Japan	0.0030	0.0019	0.0021	0.0000	0.0006	0.0010	0.0001	0.0001
Korea	0.0033	0.0036	0.0025	0.0002	0.0009	0.0004	0.0002	0.0005
Latvia	0.0038	0.0038	0.0038	0.0005	0.0011	0.0000	0.0005	0.0011
Lithuania	0.0038	0.0038	0.0037	0.0006	0.0026	0.0000	0.0004	0.0010
Mexico	0.0035	0.0035	0.0027	0.0011	0.0014	0.0005	0.0012	0.0004
Netherlands	0.0037	0.0037	0.0022	0.0003	0.0012	0.0002	0.0005	0.0003
Norway	0.0037	0.0033	0.0036	0.0006	0.0012	0.0001	0.0007	0.0004
Poland	0.0037	0.0037	0.0032	0.0003	0.0016	0.0002	0.0005	0.0003
Portugal	0.0037	0.0037	0.0036	0.0002	0.0012	0.0001	0.0003	0.0011
Slovak Republic	0.0038	0.0038	0.0036	0.0003	0.0007	0.0000	0.0002	0.0009
Slovenia	0.0038	0.0038	0.0037	0.0002	0.0020	0.0000	0.0002	0.0006
Spain	0.0036	0.0033	0.0030	0.0002	0.0008	0.0003	0.0003	0.0030
Sweden	0.0036	0.0034	0.0034	0.0003	0.0009	0.0001	0.0006	0.0011
Switzerland	0.0037	0.0036	0.0032	0.0000	0.0008	0.0001	0.0001	0.0006
Turkey	0.0035	0.0031	0.0034	0.0038	0.0038	0.0004	0.0038	0.0029
United Kingdom	0.0035	0.0034	0.0028	0.0004	0.0009	0.0006	0.0005	0.0004
United States	0.0000	0.0000	0.0000	0.0004	0.0018	0.0038	0.0003	0.0004

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