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HOW VULNERABLE ARE HIGH-INCOME COUNTRIES TO THE COVID-19 PANDEMIC? AN MCDM APPROACH

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Abstract: *This paper tries to determine the most vulnerable points of high–income countries during the Covid-19 pandemic in an MCDM setting. For this aim, we use the entropy method to obtain criteria weights and the PIV method for the comparisons. We employ a wide range of criteria that account for political, demographic, capacity, and Covid-19 indicators including vaccination. Our sample consists of 40 HICs. The results reveal that countries with less equitable healthcare systems and with more vaccine hesitancy are more vulnerable to Covid-19. Hospital bed capacity, a strict government policy, and a lower percentage of the population who smoke add to the success of countries in this combat. We compare our findings with SAW and MAUT techniques as well and obtain very similar rankings. Therefore, we conclude that the PIV method can be used for national performance evaluations with a reduced rank reversal problem and computational simplicity.*

Key words: *High–Income Countries, MCDM, Entropy Method, PIV Method, Covid-19 Pandemic.*

1. Introduction

The unexpected start of the Covid-19 pandemic in 2020 has exacerbated debates over how to respond to the spread of infectious disease nationwide. At the beginning of the pandemic, all countries applied similar strategies. Within time, it turns out that the same strategies have not provided parallel results for everybody. The national performance, in other words, the success in this pandemic is highly related to the countries' own dynamics. During the pandemic, it is put forth clearly that low– and middle–income countries (LMICs) are more open to the spread of this disease and its negative consequences due to lack of social distancing, crowded households, extreme

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poverty, lack of hygiene and medical capacity. The high–income countries (HICs), however, have more resources to fight against the pandemic. Yet, some of them have not shown a performance as good as prior expectations. This study examines the areas and the reasons that HICs are also fragile against the pandemic. We contribute to the Covid-19 literature by assessing the vulnerabilities of 40 HICs in the combat against this disease within a multicriteria decision-making framework. For this framework, we identify an exhaustive set of criteria including vaccination, population characteristics, per capita income status, Covid-19 indicators, healthcare capacity, and governmental policy indicators. Criteria weights are defined based on the entropy method. Then, we evaluate the national performances of HICs by using a novel MCDM technique, namely Proximity Indexed Value (PIV) method. More specifically, the aims of this paper are threefold: i. Evaluating the national performance of 40 HICs in the combat against the Covid-19 pandemic with an MCDM framework; ii. comparing the relative importance of criteria and defining in what areas HICs are more vulnerable to such a disease, iii. determining the contribution of vaccination policies to pandemic management.

In this paper, we have several motivations to limit our sample only to HICs rather than LMICs. The first reason is the reports and rankings by Global Health Security Index (GHS Index). GHS Index report (2019) noted that infectious diseases can be a significant risk for the international economy and security as much as climate change or political instabilities[1]. GHS index evaluates the relative capabilities and provides a benchmark for 195 countries in 6 different categories. Although this report emphasizes that none of the countries is perfectly ready for future pandemics, the HICs have a much higher GHS Index score compared to the other countries, so they are the best-prepared ones. No doubt, wealth is an important weapon to manage the spread and effects of the pandemic. In LMICs, however, the resources and the availability of measures that can be taken are limited. This is one of the reasons that previous literature mostly concerns the fight that is going on (for example, Türkoğlu & Tuzcu, 2021). We, on the other hand, focus on the possible flaws in the pandemic management of the HICs, the least vulnerable and most wealthy countries.

GHS Index (2019) indicates that the USA and the UK share the top first and second places. Despite their high rankings, during the Covid-19 pandemic, these countries have shown a relatively bad performance in terms of the number of new cases and deaths. In fact, most HICs are criticized for their delayed responses to the Covid-19 pandemic. Some low-ranked countries like Vietnam and China, on the other hand, have a relatively good performance in the battle against Covid-19. This conflicting GHS index score and performance situation leads us to the question: Why is it not possible for some HICs to obtain the best results against Covid-19 despite the existence of all resources? In what areas are they more vulnerable?

The second reason to investigate the current situation of HICs is the availability of vaccines. Chen (2021) notes that the vaccination rate can only be an important determinant in the progress of the current pandemic in high and upper-middle-income countries. By February 2022, every 2 of 3 people in HICs have been vaccinated against Covid-19, while this rate is every 1 in 8 people in low–income countries.[2] This situation widens the gap between HICs and other countries, but also the inequity inside the HICs. Marti and Puertas (2021) state that vulnerability shows the degree of a society's potential to protect and make vulnerable populations more resilient to

[1] https://www.ghsindex.org/wp-content/uploads/2019/10/2019-Global-Health-Security-Index.pdf Accessed 21 February 2019.
[2] https://data.undp.org/vaccine-equity/accessibility/ Accessed 21 February 2022.

disasters. Vaccination is another determinant of vulnerability. Therefore, vaccination status must be taken into account while discussing the national performance against Covid-19. However, at the time of this research, taking vaccination into account as a determinant is only possible when the sample is restricted with the HICs due to the global availability of Covid-19 vaccines. Therefore, vaccine availability becomes another motivation to concentrate only on the HICs.

Hodgins and Saad (2020) indicate that now the aim in the fight against Covid-19 is not to keep the country completely virus–free. Fisher et al., (2020) indicate that after two years passed with Covid-19, "flatting the curve" by implementing severe restrictions is not a viable option anymore. Now, the aim has become the ability to live with this disease, that is to say, to maximize benefit while minimizing the harm caused by Covid-19 precautions. Therefore, we need to determine the most vulnerable points of countries even among the wealthiest ones. However, the aim of "maximizing benefit while minimizing harm" is conflicting in nature. Fisher et al., (2020) also argue that there is no one reliable indicator of performance against Covid-19. Many criteria are required to assess the ability to live with Covid-19. Considering the need for many performance indicators and the conflicting nature of Covid-19, we believe that the best setting to assess countries is to employ an MCDM framework. With this setting, we believe that some dimensions that the GHS Index overlook will be taken into account, and a better country ranking will be provided. This study also contributes to the scarce literature on the application of MCDM techniques to Covid-19-related problems.

The application of MCDM provides reliable solutions only when the compared units are similar. Previous studies often cluster their sample. For example, Aydın and Yurdakul (2020) apply k–means clustering first, then compare the country performances with a data envelopment analysis. Some consider OECD (i.e. Yiğit, 2020; Çalış Boyacı, 2021) or the European countries (i.e. Marti & Puertas, 2021; Markowicz & Rudawska, 2021) with an MCDM setting. As noted by Hodgins and Saad (2020), these countries are very different in terms of demographic characteristics, geography, and economies. Comparing non–homogenous groups will not provide a correct picture of the real performance of these countries. We believe that examining a less analyzed and rather homogenous sample with HICs will contribute to the literature in order to show their vulnerabilities and sample-specific policy suggestions will be possible.

In this study, we employ an entropy-based proximity indexed value (PIV) approach to evaluate the national performance rankings of HICs. The entropy method is a well–known objective criteria weighting technique that has been used in several MCDM problems. The weights, in this method, are free from the decision–makers' judgments and determined based on the differences among criteria. Hence, it is consistent with the nature of Covid-19. The PIV method, on the other hand, calculates the distance from the ideal solution and ranks alternatives accordingly. Previous studies, such as Khan et al., (2019) and Zamiela et al., (2021: 8) find that this method provides robust rankings when compared to other well–established methods, such as TOPSIS. To test the robustness of our results, we also crosscheck the rankings from the PIV method with two other approaches, namely Simple Additive Weighting (SAW) and Multiattribute Utility Theory (MAUT). The Spearman rank correlations and Wilcoxon rank tests show that rankings from these two approaches are highly correlated with those obtained from the PIV technique and there is no statistically significant difference between the means. Therefore, we conclude that our findings are robust.

The results of this study reveal the HICs' most vulnerable areas against the current pandemic which is different than LMICs. In the LMICs, Türkoğlu, and Tuzcu (2021) show that the weakest point in this struggle is the level of extreme poverty which determines the ability of social distancing and achieving hygiene standards. In the

HICs, income has a different role. Its importance in the analysis is much less than LMICs. The allocation of the available resources, rather than their absolute amount, becomes important for the success of the Covid-19 pandemic. This is why some strong and high GHS index scored countries, like the USA or the UK, obtain lower rankings in this analysis. The socioeconomic disadvantage within the HICs still determines the rate of success and makes the population of these countries vulnerable to Covid-19.

Vaccination policy is also another determinant of the success of HICs against the pandemic. The common point of the countries with the lowest rankings is the low vaccination rates. In fact, it is a worrisome finding despite the fact that most of the vaccines produced so far are held by HICs. The reluctance towards the vaccine is mostly due to misinformation about the vaccines and the lack of trust in governments. It is urgent that these governments adopt specific policies to strengthen trust and combat misinformation. Public figures and leadership might play a role to weaken vaccine hesitancy. Otherwise, especially the elders and the disadvantaged shares of the population in terms of sociodemographic status will continue to be open to this disease.

The novelties of this study are as follows: First, we concentrate on a less analyzed rather homogenous group of countries and determine their national performance against the Covid-19 pandemic. Second, due to the conflicting nature of the disease itself, and the pandemic management aims, we employ an MCDM setting, namely the entropy-based PIV method. In this way, we are able to apply a very new MCDM technique to a current problem. Next, since these countries are the wealthiest ones in the world, we also show in which aspects they cannot manage the pandemic efficiently despite the availability of resources. In other words, we put forth the weakest points of the HICs so that we can make policy implications for future similar diseases. Last, by discussing the role of vaccinations, we also contribute to this line of research and show possible reasons for vaccine hesitancy towards the Covid-19 vaccine.

Based on the findings, this study highlights the importance of the following policy implications: Even in the wealthiest countries in the world, socioeconomically disadvantaged groups are more open to contagious diseases, such as Covid-19. The equity in the access to the healthcare systems as well as in the distribution of other available resources is the key to the success in current and future pandemics. Countries must adopt policies that protect disadvantaged groups by providing free or at least more affordable healthcare. Vaccine hesitancy has also a vital role in the determination of country performance and vulnerability. Therefore, governments must deal with vaccine hesitancy by having transparency about vaccination policy, providing correct information, and persuading especially the disadvantaged and elder population for the necessity of the vaccines. As correctly stated by the WHO, "*no one is safe until everyone is safe.*"[3], not even in the wealthiest countries.

The rest of this study is organized as follows: The following section describes the current literature about the national performance against Covid-19 and the usage of several MCDM techniques in this issue. The third section explains our sample and choice of MCDM technique, namely the entropy-based proximity indexed value method. We present our findings in the next section. We also apply a sensitivity analysis and compare our results with other well–established MCDM techniques in the next section, and the last section concludes with managerial implications.

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[3] https://www.who.int/news-room/commentaries/detail/a-global-pandemic-requires-a-world-effort-to-end-it-none-of-us-will-be-safe-until-everyone-is-safe Accessed 04 March 2022.

2. Literature Review

Stern consequences of Covid-19 on every aspect of life have been discussed heavily in the past two years. The performance of countries against Covid-19 has caught the special interests of academics as well. In this study, we try to determine the best performing HICs and understand what are their vulnerabilities through a combination of MCDM techniques. For this aim, we can examine the current Covid-19 literature from two aspects: The studies that compare country performances with methodologies other than MCDM techniques constitute the first group. The application of MCDM methods to performance evaluations establishes the second group of papers.

In the first line of studies, country performances and success factors are discussed. Fisher, et al. (2020) argue that in the early times of the pandemic, countries took precautions without considering the situation in their own society. Now, success can be defined as the ability to live with Covid-19. Therefore, the vulnerabilities of countries must be understood and the national performance must be assessed accordingly.

Jamison et al. (2020) assess the performance of 35 countries based on the doubling times of new cases and deaths attributed to Covid-19. Their aim is to show the impacts of government policy choices both on health and economic outcomes. Aydin and Yurdakul (2020) cluster and evaluate 142 countries according to several indicators with a novel DEA approach.

Cartaxo et al., (2021) develop a vulnerability assessment model and cluster countries based on their exposed risk due to Covid-19. They adopt an entropy-based model to determine the similarity between Covid-19 exposure of countries according to 49 indicators from the social, economy, population, and health categories. They show that contrary to expectations, Covid-19 has not only hit the most vulnerable countries with low resource capacity hard but also put developed and wealthiest countries at risk. Their results indicate that the USA and Japan are among the countries at highest risk due to exposure to Covid-19. In fact, the USA has the same similarities to Covid-19 spread with India and Brazil, two highly affected countries by Covid-19.

Markowicz and Rudawska (2021) note that improvements in the healthcare system and rational decision-making are only possible through a thorough assessment of the country's performance during the Covid-19 pandemic. For this aim, they suggest an evaluation framework based on a set of demographic, epidemiological, health-related quality of life, financial resources, and access to healthcare system indicators. They develop a standardized distance measure using data from 28 European Union countries and the USA. Higher values of this measure show a better situation for the underlying country.

The second field of literature that is related to our study is the application of MCDM techniques to national performance assessments. In this area, Pal et al. (2020) forecast long term country-specific risks by using artificial intelligence to predict and cluster them as high-risk, low-risk, and recovering countries. Samanlioglu and Kaya (2020) evaluate precautions other than the healthcare system that governments apply, such as mobility restrictions, full lockdowns, school closures, and declaration of a state of emergency, by using a hesitant fuzzy AHP method. Kayapinar Kaya (2020) compares the sustainable development performance of OECD countries before and during the Covid-19 pandemic by employing the MAIRCA method. The results of this study indicate that developing countries are more vulnerable to the Covid-19 pandemic than their developed counterparts in terms of their sustainable development levels. Khan, Ali, and Pamucar (2021) offer a new fuzzy FUCOM-QFD approach for the assessment of healthcare systems during the Covid-19 pandemic that can be applied to the systems in different countries.

Alkan and Kahraman (2021) evaluate different governmental strategies and restrictions applied during the Covid-19 pandemic by using q–run orthopair fuzzy TOPSIS specification. In this model, government strategies constitute alternatives while different costs of these strategies, future loss, time, and the effects of implementing these restrictions on human rights are considered as the criteria. Their findings indicate mandatory quarantine that limits social interaction and a strict isolation strategy as the best strategy that a government can adopt in this fight.

Yiğit (2020) assesses the national performance of 36 OECD countries with the TOPSIS methodology where the countries are the alternatives and healthcare indicators are the criteria. The results from this study highlight that contrary to expectations, some countries with high healthcare expenditures and long life expectancy, are not classified among the best countries in the struggle against Covid-19. Similar to Yiğit (2020), Çalış Boyacı (2021) investigates the performances of OECD countries by employing TOPSIS, COPRAS, and ARAS methods while the criteria weights are obtained through the SWARA technique. In this study, the criteria selection also depends on healthcare statistics.

Türkoğlu and Tuzcu (2021) evaluate 22 middle–high–income countries with an extensive set of indicators, including healthcare capacity, socio–demographic situation, and Covid-19 indicators with an SDV-based ROV method. Their findings confirm that poverty levels are as important as hospital capacity. They also show that demographic characteristics, like the average population age, are a significant determinant of country performance in this battle.

Marti and Puertas (2021) examine the vulnerability of the European countries to the Covid-19 health crisis by using TOPSIS. They assess the vulnerability from a multi–viewpoint, namely from society, work, and health. Hence, the criteria selected for the MCDM framework are indicators reflecting the situation in these categories, and the countries constitute the alternatives. These criteria reflect the most vulnerable groups to the disease itself and also the economic consequences due to the restrictive measures.

Previous literature applying MCDM techniques for national performance assessment is rather scarce. Among them, some compare national performances of non–homogenous country groups such as Markowicz & Rudawska (2021), Yiğit (2020), and Çalış Boyacı (2020). Although Covid–19 does not differentiate countries, continents, or borders, it is clear that a stronger economic situation is a powerful weapon against its fight as put forth clearly by Hodgins and Saad (2020). Using a heterogeneous country group casts doubt on the obtained results.

Some of the studies, such as Çalış Boyacı (2020), Zizovic et al. (2021), and Khan, Ali, and Pamucar (2021), mostly consider healthcare indicators. Assessing national performance, however, requires a multidimensional perspective, including socio–demographic indicators, governmental attitudes, and economic situation as well as healthcare indicators (Cartaxo et al. 2021; Marti & Puertas 2021). Last, literature often focuses on LMICs (for example, Türkoğlu & Tuzcu, 2021) and their performance against Covid-19. This is a natural choice because they are in a more difficult position due to inefficiency and scarcity of available resources.

In this study, we contribute to the existing literature by concentrating on the wealthiest and rather homogenous group of countries, namely HICs with an MCDM framework. Hodgins and Saad (2020) state clearly that the strategies applied by HICs may not always be appropriate for LMICs. The reverse is also true. Besides the availability of resources, the demographic characteristics of LMICs are considerably different than HICs. Therefore, the situation against Covid-19 in LMICs may not always be representative of the current state in HICs. Despite the availability of vaccines and more resources, income inequalities and bad management affect considerably their performances in this combat.

By employing a wide selection of criteria with a multidimensional perspective, including the vaccination status, we believe that our study reflects the strongest and most vulnerable countries against Covid-19 more clearly for HICs. Based on the findings of this paper, it is possible to make policy suggestions to remedy the vulnerabilities.

3. Data and Methodology

3.1. Sample Description

This study aims to rank the performance of HICs to identify their possible weak points in the struggle against Covid-19. According to the World Bank income groups, there are 80 countries described as HICs. We identify 40 countries that have a population of over 1,000,000 people and which have complete vaccination data for the analyses. These countries are Australia, Austria, Bahrain, Chile, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong SAR, China, Ireland, Israel, Italy, Japan, Kuwait, Latvia, Lithuania, Netherlands, New Zealand, Norway, Oman, Poland, Portugal, Qatar, Saudi Arabia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Taiwan, China, Trinidad and Tobago, United Arab Emirates, United Kingdom, United States, and Uruguay. As of the date of the analysis, this sample covers 50.7% of the total cases worldwide. We use a rather homogenous sample for the analyses in terms of available resources during the pandemic.

As it is well known, GHS Index ranked most HICs as the more prepared countries in case of the existence of a contagious disease. The sample's average GHS Index score is 55.36 which is well above the 2021 world's overall average score of 38.9. Table 1 Panel A and B give descriptive statistics and Pearson correlations for total cases, total deaths, and GDP per capita for the sample to provide a general outline.

Table 1. Descriptive Statistics and Correlations for Selected Variables

Panel A. Descriptive Statistics

	Mean	**Median**	**Min**	**Max**	**Std Dev**
Total cases	211027.6	231729.5	824.397	413076	117330.7
Total deaths	1541.569	1542.045	10.339	3573.06	1096.42
GDP per capita	35478.41	29388.71	10434.78	87097.04	19711.37

Panel B. Correlations among Selected Variables

	Total cases	**Total Deaths**	**GDP per capita**
Total cases	1		
Total Deaths	0.5476*	1	
	0.0003		
GDP per capita	0.1235	-0.3385*	1
	0.4478	0.0326	

The values in parentheses show p–values. * represents significance at 5% level.

Table 1 Panel A reveals that the current pandemic situation varies considerably. Both the number of total cases and total deaths show high standard deviations. The correlations presented in Panel B indicate no significant association between income and the number of total cases. Total deaths, however, are significantly and negatively correlated with GDP per capita. It seems that countries with higher income experience lower deaths which highlights the importance of wealth in this combat.

3.2. Methodology

Many studies in the literature, such as Cartaxo et al. (2021) and Marti & Puertas (2021) state that the struggle against Covid-19 has many aspects that the countries deal with at the same time not only healthcare status. Instead, studies must adopt a multi–viewpoint to describe country performances. MCDM, in this sense, is a very useful tool to evaluate many and often conflicting criteria and determine the best to worst performing alternatives. We employ the entropy-based PIV method as an MCDM approach in this paper to rank the performance of HICs while considering policy, healthcare capacity, and demographic criteria as well as Covid-19 related indicators. The findings are also compared with two other MCDM approaches, namely SAW and MAUT as sensitivity analysis. The general framework of this study is summarized in Figure 1 for clarity.

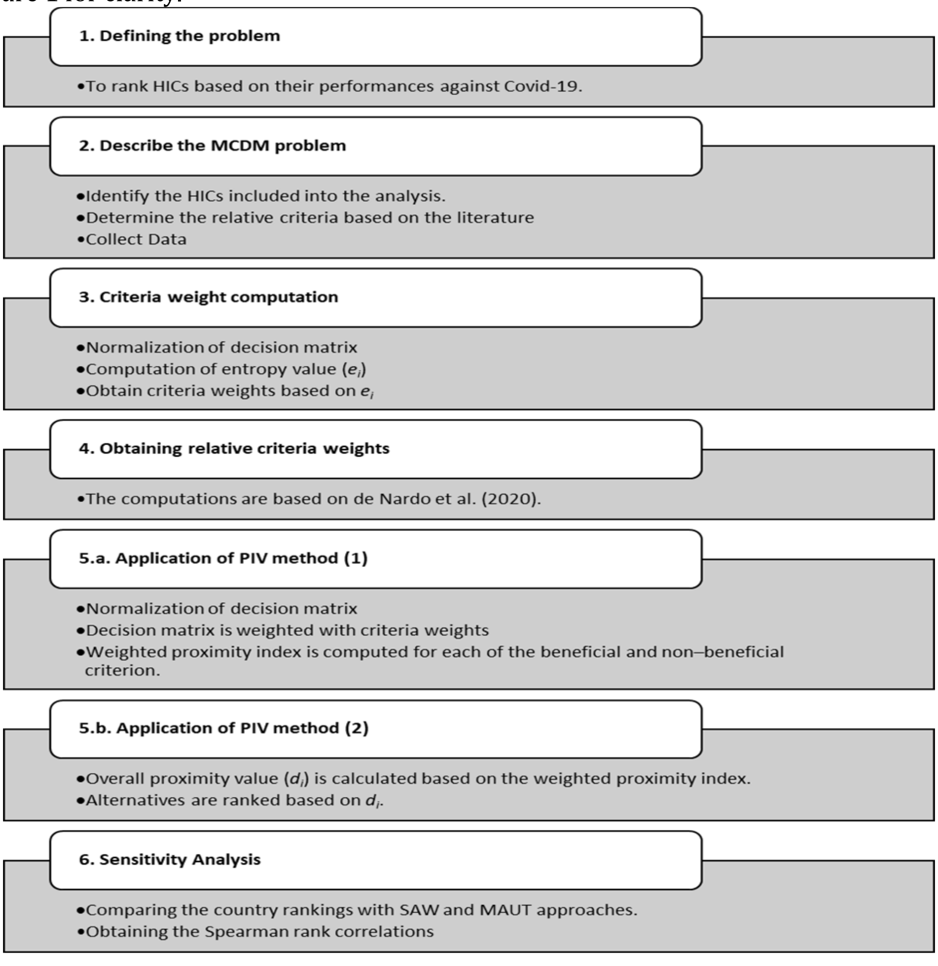

Figure 1. The framework of this study

Following Cartaxo et al. (2021), we identify 14 criteria including political, demographic, capacity, and Covid-19 indicators and vaccination policy, in order to provide a general view for each country against the pandemic. The selection of criteria is based on the previous studies that evaluate different groups of countries during the Covid-19 pandemic, i.e. Aydin & Yurdakul, 2020; Yiğit, 2020; Arsu, 2021; Cartaxo et al., 2021; George et al., 2020; Nguyen et al., 2021; Fisher, Teo & Nabarro, 2020.

As in Markowicz and Rudawska (2021), the criteria selection is based on a set of questions. Demographic indicators are chosen to answer whether the population is more open to catching Covid-19 and its negative consequences. Capacity indicators try to measure whether the healthcare system can deal with Covid-19 in terms of human resources and infrastructure. Policy and Covid-19 indicators aim to assess whether the governmental response is effective in terms of preventing the spread of the disease and deaths.

These criteria, their definition, and the sources that the data comes from can be seen in Table 2.

Table 2. The Criteria Employed in the Analyses, and Data Sources

Indicators	Criteria	Definition	Data Source
Policy indicators	Government Response	Government Response Stringency Index: A composite measure based on 9 response indicators value from 0 to 100.	https://www.bsg.ox.ac.uk/research/research-projects/Covid-19-government-response-tracker (Access date: 04.01.2022)
Capacity indicators	Hospital Beds Per Thousand	The number of hospital beds per 1000 people in a given country.	https://ourworldindata.org (Access date: 04.01.2022)
	Current Health Expenditure	The amount of health expenditures as a percentage of the GDP of a given country.	The World Bank Database (2018)
	Total vaccinations per hundred	The number of vaccines applied per 1,000 people in a given country.	https://ourworldindata.org (Access date: 17.02.2022)
	Income	GDP per capita (current US$)	The World Bank Database (2020) (Access date: 04.01.2022)
Demographic Indicators	Cardiovascular Death Rate	The annual number of deaths due to cardiovascular diseases per 100,000 people in a given country.	https://ourworldindata.org (Access date: 04.01.2022)
	Diabetes Prevalence	The rate of people aged between 20 and 79 with type 1 and type 2 diabetes	https://ourworldindata.org (Access date: 06.01.2022)
	Share of adults who smoke	The share of adults, aged 15 years and older, who smoke any tobacco	https://ourworldindata.org (Access date: 06.01.2022)

		product on a daily or non-daily basis.	
	Population ages 65 and above	The rate of people age 65 and above to the total population in a given country.	The World Bank Database (2020) (Access date: 04.01.2022)
	Population density	Population density (people per sq. km of land area)	The World Bank Database (2020) (Access date: 04.01.2022)
Covid-19 Indicators	Total Cases	The number of total confirmed Covid-19 cases per 1,000,000 people	https://ourworldindata.org (Access date: 17.02.2022)
	Total Deaths	Total number of deaths due to Covid-19 per 1,000,000 people	https://ourworldindata.org (Access date: 17.02.2022)
	Total Recovered	The number of patients recovered from Covid-19 infection per 1,000,000 people.	https://www.worldometers.info/coronavirus (Access date: 17.02.2022)
	Total Tests	The number of total tests to diagnose Covid-19 infections per 1,000 people.	https://ourworldindata.org (Access date: 17.02.2022)

3.2.1. Entropy Method

The entropy approach is a widely used method to weight criteria in MCDM studies. It is first developed by Shannon (1948) and employed in many areas including the areas of bank diversification (Çınar et al. 2018), stock markets (Baydaş & Elma 2021), robotics (Chodha et al., 2022), power generation problems (Emovon & Samuel, 2017) and informatics (Kannan & Thiyagarajan, 2021). It is a reliable weighting method and provides high reliability in the objective criteria determination (Dashore et al., 2013: 2183; Işık and Adalı, 2017: 85; Gupta and Kumar, 2022: 78).

It is an easily applicable objective weighting method in which decision-makers are not included in the process of establishing the relative importance of criteria. Instead, this method relies on the contrasts among criteria, and the weights are determined accordingly (Mukhametzyanov, 2021). In other words, the information in the decision matrix and the relation between alternatives and criteria become highlighted in the entropy method (Žižovic, Miljkovic & Marinkovic 2020), which is consistent with the nature of the Covid-19 pandemic.

To obtain criteria weights with the entropy method, the decision matrix is normalized through Eq. (1).

$$y_{ij} = \frac{x_{ij}}{\sum_{j=1}^{m} x_{ij}} \quad (1)$$

There are m alternatives and n criteria, *i* indicates the total number of criteria and *j* indicates the number of alternatives, where i=1,2,…,n and j=1,2,…,m. "x_{ij}" are the elements of the decision matrix, while, y_{ij} reflects the normalized matrix.

In the second step, the entropy value, e_i, is computed for each criterion as shown in Eq. (2).

$$e_i = -k \sum_{j=1}^{m} y_{ij} \ln(y_{ij}) \quad (2)$$

Where is k a constant term stated as k=1/ln(m) in order to assure that e_i lies between 0 and 1.

Finally, weights for each criterion are computed as stated in Eq. (3).

$$\mathrm{w_i} = \frac{1-\mathrm{e_i}}{\sum_{i=1}^{n} 1-\mathrm{e_i}} \quad (3)$$

3.2.2. Proximity Indexed Value (PIV) Method

The PIV method depends on the idea that the selected alternative must be closest to the ideal solution/ the best value. To do so, a proximity index is calculated by the linear distance of each normalized alternative from the best alternative's value (Mufazzal & Muzakkir, 2018: 430). PIV method provides the advantages of reduced rank reversal problem observed in many MCDM techniques such as TOPSIS as well as computational simplicity. It also offers robust rankings when the results are compared to many other MCDM techniques (Khan et al., 2019; Zamiela et al., 2021: 8). In fact, Goswami et al., (2021: 1154) indicate that the PIV method provides more reliable solutions when its rankings are compared to traditional techniques, such as AHP, TOPSIS, COPRAS, and VIKOR.

The steps of the PIV method can be described below (Mufazzal and Muzakkir, (2018: 430) and Khan et al. (2019)):

First of all, the decision matrix is set and normalized as follows:

$$\mathrm{R_i} = \frac{Y_i}{\sum_{i=1}^{m} {Y_i}^2} \quad \text{i=1,...,m;} \quad (4)$$

Yi is the decision value of the ith alternative.

The next step is to compute the weighted normalized decision matrix as shown in Eq. (5):

$$\mathrm{v_i} = w_i * \mathrm{R_i} \quad (5)$$

Where wi, is the criterion weight.

This step is followed by the computation of the Weighted Proximity Index (WPI), which is shown by ui, by using Eq. (6) and Eq. (7):

$$u_i = v_{max} - v_i \ \text{(for beneficial criteria)} \quad (6)$$

$$u_i = v_i - v_{min} \ \text{(for non–beneficial criteria)} \quad (7)$$

The final step is to obtain the overall proximity value, d_i.

$$d_i = \sum_{j=1}^{n} u_i \quad (8)$$

The alternatives are ranked based on the di value obtained from Eq. (8). The lowest di score represents the minimum deviation from the best solution, therefore becomes the top alternative.

4. Findings

As explained below, the MCDM analysis begins with the normalization of the decision matrix by using Eq. (1). Second, entropy values are obtained by employing Eq. (2) and criteria weights are found through Eq. (3). The criteria cardiovascular death rate, diabetes prevalence, the share of adults who smoke, the population aged 65 and above, population density, total cases, and total deaths, are non–beneficial, whereas the criteria government response, hospital beds per thousand, current health expenditure, total vaccinations per hundred, income, total recovered, and total tests are beneficial. The criteria weights are provided in Table 3.

Table 3. Criterion Weights

Criteria	Cardiovascular Death Rate	Diabetes Prevalence	Share of adults who smoke	Population aged 65+	Population density	Total Cases	Total Deaths	Total vaccinations	Government Response	Hospital Beds	Current Health Expenditure	Income	Total Recovered	Total Tests
w_j	0.0691	0.0565	0.0822	0.0844	0.0637	0.0705	0.0541	0.0773	0.0814	0.0913	0.0710	0.0677	0.0691	0.0616

Table 3 reveals that the entropy method puts the highest weight on hospital bed capacity, followed by demographic characteristics and government response. The entropy method determines criteria weights based on the contrasts of the selected attributes of the alternatives. This means that the countries in the sample vary the most in terms of hospital capacity, population age, smoking habits, and government response. Total vaccinations per hundred people have the 5th position. The sample has similar characteristics in terms of total Covid-19 tests and deaths.

Cartaxo et al. (2021) argue that to understand the true nature of pandemic management, risk factors, their effects, and interactions must be determined, and governmental policies must be made accordingly. Based on the weights shown in Table 3, it is also possible to make such a relative assessment for pairs of criteria. Following De Nardo et al. (2020), we create the matrix of criteria weights comparison to demonstrate the interactions between criteria more clearly as suggested in Cartaxo et al. (2021). This relative assessment can be observed in Table 4.

Table 4. Matrix of Comparison for Criteria Weights

		Cardiov. Death Rate	Diabetes Prev.	Share of smoking	Pop. ages 65+	Pop. density	Total Cases	Total Deaths	Total vaccination	Gov. Response	Hospital Beds	Current Health Exp.	Income	Total Recovered	Total Tests
	wj	0.069	0.057	0.082	0.084	0.064	0.070	0.054	0.077	0.081	0.091	0.071	0.068	0.069	0.062
Cardiovascular Death Rate	0.069	1.000	1.223	0.841	0.818	1.085	0.980	1.278	0.894	0.849	0.757	0.973	1.020	1.000	1.121
Diabetes Prevalence	0.057	0.818	1.000	0.688	0.669	0.888	0.802	1.045	0.731	0.694	0.619	0.796	0.834	0.818	0.917
Share of adults who smoke	0.082	1.189	1.454	1.000	0.973	1.290	1.166	1.519	1.063	1.009	0.900	1.157	1.213	1.189	1.333
Population ages 65+	0.084	1.222	1.494	1.028	1.000	1.326	1.198	1.561	1.092	1.037	0.925	1.189	1.246	1.222	1.370
Population density	0.064	0.922	1.127	0.775	0.754	1.000	0.904	1.177	0.824	0.782	0.697	0.897	0.940	0.922	1.033
Total Cases	0.070	1.020	1.247	0.858	0.835	1.107	1.000	1.303	0.912	0.865	0.772	0.992	1.040	1.020	1.143
Total Deaths	0.054	0.783	0.957	0.658	0.641	0.849	0.767	1.000	0.700	0.664	0.592	0.762	0.798	0.783	0.877
Total vaccinations	0.077	1.119	1.368	0.941	0.916	1.214	1.097	1.429	1.000	0.949	0.847	1.089	1.141	1.119	1.254
Government Response	0.081	1.178	1.441	0.991	0.965	1.279	1.155	1.506	1.053	1.000	0.892	1.147	1.202	1.179	1.321
Hospital Beds	0.091	1.321	1.615	1.111	1.081	1.434	1.295	1.688	1.181	1.121	1.000	1.286	1.348	1.321	1.481
Current Health Expenditure	0.071	1.028	1.257	0.864	0.841	1.115	1.008	1.313	0.919	0.872	0.778	1.000	1.048	1.028	1.152
Income	0.068	0.980	1.199	0.825	0.802	1.064	0.961	1.253	0.876	0.832	0.742	0.954	1.000	0.980	1.099
Total Recovered	0.069	1.000	1.223	0.841	0.818	1.085	0.980	1.278	0.894	0.849	0.757	0.973	1.020	1.000	1.121
Total Tests	0.062	0.892	1.091	0.750	0.730	0.968	0.875	1.140	0.797	0.757	0.675	0.868	0.910	0.892	1.000

W_j is the weight for each criterion

The matrix shown in Table 4 can be read from left to right and it is not symmetric. Although hospital capacity has the highest weight in Table 3, the findings from this matrix indicate that it is slightly more important than the share of the population that has 65 years and older (1.08) and the share of the population who smokes (1.11). However, it is 1.615 times more important than diabetes prevalence and 1.688 times more important than total deaths attributed to Covid-19. Vaccination policy is more important than the number of deaths (1.429), diabetes prevalence in the country (1.368), total tests (1.254), and population density (1.214). It is also as important as current health expenditures. GDP per capita is one of the least important criteria in this analysis. These findings confirm that demographic and socioeconomic factors are as important as medical capacity when it comes to preventing cases and deaths as stated in Wildman (2021).

Once the criteria weights are decided using the entropy method, the rankings of HICs are computed using the steps of the PIV technique. The rankings presented in Table 5 are based on the normalized decision matrix that is obtained by employing Eq. (4) [4].

Table 5. The Rankings Obtained from The PIV Technique

Countries	d_i	Ranking
Austria	0.1180	1
Japan	0.1258	2
Cyprus	0.1351	3
Ireland	0.1354	4
Switzerland	0.1361	5
Australia	0.1364	6
Denmark	0.1389	7
France	0.1408	8
Norway	0.1412	9
Germany	0.1430	10
New Zealand	0.1444	11
Israel	0.1453	12
United Arab Emirates	0.1487	13
United Kingdom	0.1521	14
Finland	0.1536	15
Netherlands	0.1544	16
Italy	0.1546	17
United States	0.1554	18
Qatar	0.1557	19
Taiwan, China	0.1565	20
Portugal	0.1621	21
Kuwait	0.1626	22
Greece	0.1632	23
Oman	0.1637	24
Spain	0.1653	25
Saudi Arabia	0.1661	26
Czech Republic	0.1669	27
Uruguay	0.1669	28

[4] In the papers using MCDM techniques, it is common to provide initial decision matrix and normalized matrix. However, having 40 countries and 14 different criteria makes these matrices rather hard to examine. To conserve space, we do not provide them inside the main text of this paper, but they are available on request.

Countries	d_i	Ranking
Slovenia	0.1671	29
Sweden	0.1673	30
Slovak Republic	0.1704	31
Chile	0.1721	32
Lithuania	0.1741	33
Poland	0.1744	34
Estonia	0.1755	35
Bahrain	0.1787	36
Trinidad and Tobago	0.1839	37
Croatia	0.1844	38
Latvia	0.1848	39
Hong Kong SAR, China	0.2080	40
Average	0.1582	

The findings in Table 5 reveal that the best-performing countries in the sample only consisting of HICs are Austria, Japan, and Cyprus. Among these three countries, Japan has the highest GHS Index score in 2021 (60.5), while Austria has the average score (56.9) and Cyprus is below the average (41.9). The worst performing countries, however, are Croatia, Latvia, and Hong Kong, China. The USA has the 18th ranking, while the UK has the 14th place alongside the criticisms toward the GHS index. The average proximity indexed value is 0.1582.

When the best performing countries are closely examined, it is seen that Austria has one of the highest hospital bed capacities per thousand people and applied strict lockdown policies. Although the share of adults who smoke is high in this country, its population is relatively younger than the HICs considered in this analysis.

Japan has an elder population, but the percentage of people with a smoking habit is relatively lower. It is the country with the highest hospital capacity per thousand people. The percentage of health expenditure in Japan is also very high.

Since the beginning of the pandemic, Australia and New Zealand have applied very strict lockdown policies with speed testing[5]. Their unique geography and traveling restrictions also help to control the spread of new cases. Although they have hospital capacity and health expenditures on the sample average, Australia and New Zealand obtain relatively better rankings in the sample. In this success, very small numbers of total Covid-19 cases and Covid-19 caused deaths, as well as very low population density, play a role as well. Wilson (2021) also states the importance of the strong leadership that New Zealand exhibits during the pandemic as one of the keys to success in pandemic management.

Germany has the largest population in Europe but obtains a high ranking in our analysis. As noted in Cartaxo et al., (2021), its mass testing policy provides the country with a lower incidence rate. Comparing the UK, Germany has been more successful in terms of cases and deaths attributed to Covid-19 despite the UK's clear advantage of population density and population age. When closely examined, it is seen that Germany is one of the countries with the highest hospital capacity. Its health expenditures are also above the sample average.

Markowicz and Rudawska (2021) find that the USA, alongside Ireland, Sweden, and Luxembourg, is the country with the best healthcare system capacity. This is confirmed by our sample as well: The USA has the highest health expenditure among the HICs accounted for in this sample. The share of health expenditures of the UK is

[5] https://www.who.int/westernpacific/news-room/feature-stories/item/new-zealand-takes-early-and-hard-action-to-tackle-covid-19 Accessed 28 February 2022.

also above the sample average. Yet, these two countries obtain average rankings in Table 5. It is interesting to note that the number of total deaths attributed to Covid-19 is well above the sample average for these countries. Despite these high levels of health expenditures, their hospital capacity per thousand people is one of the lowest among the HICs considered in this analysis. These countries are known for their low capacity of government response and control particularly at the beginning of the pandemic. Cartaxo et al., (2021) attribute the very high rate of mortality observed in the USA and the UK to the burden on the hospital system. They also criticize especially the USA for the lack of equity in the healthcare system. Our findings confirm the overall result put forth by Cartaxo et al., (2021) that it is not possible to efficiently manage the available healthcare resources, no matter how vast they are, without providing equity in the system. Our findings are also in line with Yiğit (2021) that high healthcare expenditures and long life expectancy are not enough to describe the best countries in the struggle against Covid-19.

Wildman (2021) indicates that, in developed countries like the UK and the USA, health outcomes are a factor of income inequality, which also strongly affects the socioeconomic vulnerability inside societies. Particularly during the Covid-19 pandemic, it is observed that if the percentage of people with low income and insecure jobs increases in a country, their vulnerabilities to disease increases, so the country's performance decreases. This situation describes the mid-ranking of the USA. For the UK, the poorest areas are most affected which contributed to the worsening of the country's rankings.

As in the UK, the Netherlands also demonstrates a lower performance and obtain the 16th ranking despite its high preparedness level and the strong healthcare system. Marti and Puertas (2021) emphasize that the new Covid-19 cases in this country rose very quickly at the beginning of the pandemic despite their very small household size. The initial herd immunity strategy that the Netherlands applied alongside the UK played a significant role in this low performance.

The Nordic countries in our sample, namely Norway, Denmark, Finland, and Sweden, have obtained different performance rankings. Among these countries, Denmark and Norway have the 7th and 9th positions respectively. Finland has the 15th ranking, while Sweden demonstrates a low performance with 30th place among 40 countries in the sample. They have similar demographic characteristics in terms of age and chronic disease prevalence.

All these countries implement less than average strict restrictions, but the smoothest government response belongs to Sweden. Since the first cases of Covid-19, Sweden has claimed that the pandemic might prolong for an indefinite period, and very strict lockdowns would be hard to continue (Gordon, Grafton & Steinshamn 2021). Our data also reveals that the share of adults who smoke is much higher in Sweden than in other Nordic countries and the sample average. Therefore, compared to other Nordic countries, Sweden has experienced more deaths due to Covid-19 which contributed to its low ranking. Among these countries, Denmark has applied more social distancing measures than others since the beginning of the pandemic (Gordon, Grafton & Steinshamn 2021).

Hong Kong adopted a strict policy toward Covid-19, applied mass testing, and has experienced a much smaller number of cases than most Western countries. Yet, it still shares the lowest ranking with Latvia and Croatia. Its low scorecard can be attributed to the distrust in government applications and the high burden on the healthcare system (Silver, 2022).

When the worst performing countries are investigated, one can observe the following common points: Croatia, Hong Kong, and Latvia have an elder population with a relatively high percentage of people who smoke. Their hospital capacity and the percentage of health expenditures are among the last in the sample.

The HICs considered in this analysis do not show a very high dispersion in terms of the number of vaccinations applied against Covid-19. Yet, the countries with the worst performance during the pandemic have lower vaccination rates, particularly Croatia, than the rest. Misinformation and lack of trust in the government caused an important delay in vaccination rates in Latvia, while the delta variant hit the country hard[6]. Croatia shares similar vaccination rates with Latvia as well.

Despite its high level of development and available resources, Hong Kong exhibits a very low scorecard in the pandemic. The country is criticized due to the delayed vaccination policy[7] as well.

Our findings regarding vaccination confirm the prior evidence put forth by vaccine hesitancy literature. For instance, Aw et al. (2021) show that vaccine hesitancy toward Covid-19 is the highest in Hong Kong and the USA. When compared to LMICs, they state that this hesitancy has much more severe consequences on HICs, since vaccine hesitancy affects less the vaccine uptake decision in LMICs. Aw et al. (2021) also indicate that vaccine hesitancy in HICs is more common among non–White, younger and female populations with low socioeconomic status. That is, even in HICs, vaccine hesitancy makes the already vulnerable population more open to the negative consequences of the Covid-19 pandemic.

Our findings, in line with previous literature such as Cartaxo et al., (2021) and Wildman (2021) once more emphasize that factors only related to the healthcare system and socioeconomic status are not enough to designate the true course of events when it comes to Covid-19 pandemic. Political and demographic indicators must also be considered to determine vulnerabilities.

We also show that the most pronounced factors in the determination of success for HICs and LMICs are different. Türkoğlu and Tuzcu (2021) demonstrate that for upper-middle-income societies, population density and extreme poverty play vital roles in pandemic management. In countries where extreme poverty is a serious case, it is not easy to access basic hygiene materials and apply social distancing. For HICs, however, income has a relatively low significance compared to extreme poverty. Instead, for the HICs, the distribution of the available resources becomes more important than the number of resources. Here, the success in pandemic management is determined mostly by the equity in the healthcare system and the relative income inside the country.

In contrast to the LMICs, population density does not become prominent as a factor of success in the pandemic management of HICs since these countries are mostly less dense in population even in the major cities. The ratio of the elder population especially comes to the forefront in the HICs. As the population gets older, the rate of comorbidities and the burden on the overall healthcare system. Interestingly, the prevalence of chronic diseases, like diabetes or cardiovascular diseases, in societies is not a determinant of HICs performance. This finding can be attributed to the good healthcare services in these countries. Yet, our findings reveal that hospital bed capacity in HICs is as important as for LMICs.

Based on the results presented in this study, we can conclude that the lack of equity in access to the healthcare system makes HICs vulnerable to the pandemic as well as

[6] https://www.euronews.com/my-europe/2021/08/30/how-distrust-and-disinformation-have-left-latvia-lagging-on-vaccine-rollout Accessed 27 February 2022.

[7] https://www.bloomberg.com/news/articles/2022-02-24/why-hong-kong-is-now-one-of-the-worst-places-to-be-in-covid-era Accessed 27 February 2022.

the national healthcare capacity. It is seen that the already vulnerable share of society is very open to the risks of Covid-19 as well. Population characteristics, particularly the prevalence of smoking and age, are weak points of HICs as well.

Although HICs have access to the Covid-19 vaccinations more than any other societies, countries with low performance have the lowest vaccination rates in the sample. It is more worrisome in HICS than LMICs. This resistance to the vaccine is mostly due to the lack of confidence in government policies and misinformation about Covid-19. Vaccine hesitation makes HICs more vulnerable to a preventable disease.

5. Sensitivity Analysis

In this section, we compare the rankings of HICs that are obtained with the PIV method with two other well-known MCDM techniques, namely Simple Additive Weighting (SAW) and Multiattribute Utility Theory (MAUT). SAW method is also known as the Weighted Sum Model in the literature. The advantage of this model lies in the logic that depends on the proportional linear transformation of raw data based on the weighted average so that the relative ranking of standardized scores does not change. (Afshari et al., 2010). MAUT, on the other hand, is a systematic method that defines and analyzes more than one variable to ensure a common platform for the decision-making process. The key factor in the MAUT techniques is to obtain a utility function that depends on single utility functions and their respective weightings (Kim & Song, 2019).

The applications of SAW and MAUT depend on the weights obtained from the entropy method as in the PIV technique. The country rankings provided by these three methods are compared in Table 6.

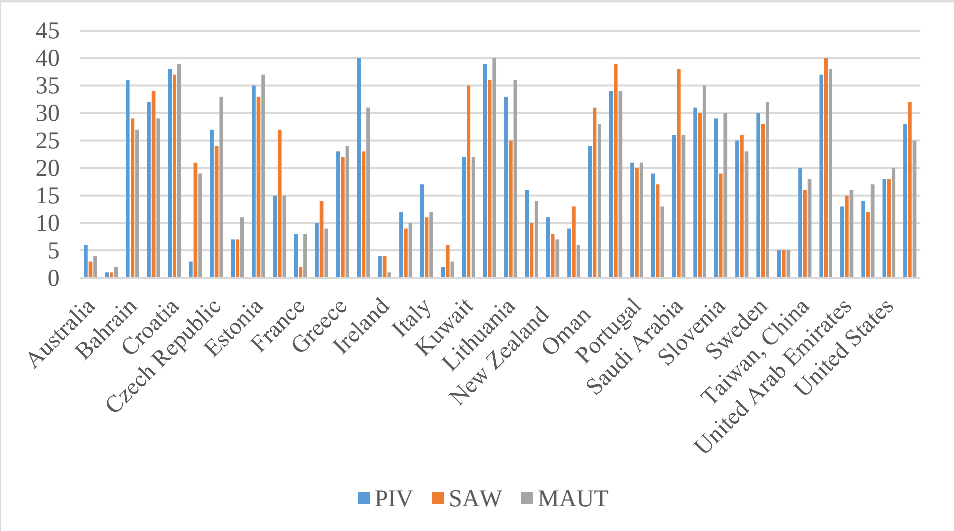

Table 6. The Comparison of Rankings from the PIV, SAW, and MAUT Techniques

The visual comparison in Table 6 demonstrates very parallel rankings for all three methods. All three methods identify the same countries as the best performing and worst-performing ones and the rankings are consistent with each other. This finding is also confirmed with two non–parametric tests, namely Spearman rank correlations and Wilcoxon rank tests. With Spearman rank correlations, we are able to observe the association between rankings, while the Wilcoxon rank test analyzes the equality of mean ranks. The results are demonstrated in Table 7.

Table 7. Spearman Rank Correlations and Wilcoxon Rank Tests for PIV, SAW, and MAUT

	PIV	**SAW**	**MAUT**
PIV	1		
SAW	0.8473*	1	
	0.0000		
MAUT	0.9360*	0.8809*	1
	0.0000	0.0000	
H_0	**PIV=SAW**	**PIV=MAUT**	
Z	0.492	0.027	
p-value	0.6228	0.9784	

The upper part of Table 7 demonstrates Spearman rank correlations. The findings point out that correlations among PIV, SAW, and MAUT are significant at 0.01 level and positive. The lowest correlation coefficient is 0.8473. In other words, a strong association in the same direction exists between PIV and SAW and between PIV and MAUT techniques. The bottom part of the table tests the null hypothesis of the equality of mean ranks for the PIV and SAW and the PIV and MAUT, respectively. The p–values are well above any acceptable significance level meaning that the mean rankings of PIV are not different from than SAW or MAUT rankings.

The sensitivity analysis confirms that PIV provides similar rankings to other MCDM techniques while offering a reduced rank reversal problem and computational advantages.

6. Conclusion

This paper focuses on the vulnerable parts of the HICs during the Covid-19 pandemic in an MCDM setting while considering a wide set of demographic, policy, capacity, and Covid-19 indicators, including vaccination policy. Our results reveal significant differences between HICs and LMICs in terms of success against this disease. The most pronounced difference between the two groups of countries lies in the effects of income. In LMICs, extreme poverty is as critical as healthcare capacity since it determines the ability to apply social distancing measures and to achieve even simple hygiene standards. In HICS, however, income has a different function. Its role is less important than the LMICs. The distribution of available resources, no matter how vast they are, becomes the determinant factor of the success against Covid-19. This is the reason behind the low rankings of countries with high GHS index scores like the USA in our analysis. Without an equitable healthcare system, countries, particularly the socially disadvantaged portions of societies, are very vulnerable to infectious diseases like the current pandemic.

Prevalence of diabetes or cardiovascular diseases does not increase the vulnerability of the population of HICs very much in contrast to other countries. This result can be attributed to the good health systems of HICs. However, hospital capacity still plays an essential role in the determination of success against Covid-19.

One of the most important conclusions of our study is about the vaccination policy as a factor in country performance. We show that the lowest ranking countries also have the lowest vaccination rates. This finding cannot be attributed to the lack of vaccines in these countries because a greater portion of worldwide shots has gone to the HICs. It can be explained by the lack of trust in governments and the misinformation about the disease and the contents of vaccines. In fact, the reluctance toward the Covid-19 vaccine is more worrisome in HICS than LMICs. This hesitancy makes particularly the elder population of HICS more vulnerable to the disease and increases the rates of hospitalization and deaths. These countries must adopt policies to increase the trust in vaccinations and combat misinformation. Here, strong leadership and public figures might have an important role to increase the vaccination rates. Transparency in vaccination policies is also important to raise confidence and persuade especially the disadvantaged and elder population for the necessity of the vaccines. The protection of the vulnerable population is crucial to have a completely safe environment for all.

We also demonstrate that the disadvantaged groups, even inside the HICs, are more fragile to Covid-19 and similar diseases. The equity in the distribution of available resources and access to the healthcare system is as important as the quantity of the resources. Governments must adopt policies that facilitate access to the healthcare system, especially by making them more affordable.

Last, our sensitivity analysis shows that the PIV method provides reliable results in comparison of national performances against Covid-19 with a reduced reversal problem and provides a computational advantage.

Some limitations of this study should also be mentioned. One of the most important limitations of this study is the different vaccination types applied by different countries. In most countries, more than one type of Covid-19 vaccine is being applied. The efficiency of these different vaccines against Covid-19 may be different, but discussing it is beyond the scope of this paper. Second, the definition of death attributed to Covid-19 was not unique at the beginning of the pandemic. In time, a convergence to some has been achieved. Yet, this variation in definitions might generate a limitation when comparing the findings with other studies. The dynamic nature of the Covid-19 pandemic might limit the generalizability of our findings to some extent. However, we believe that our study is important to demonstrate the ongoing state of the pandemic in HICs. Last, it is not easy to compare the national performances of countries, since these countries may differ in several aspects. To obtain a rather homogenous sample, we rely on the World Bank's income classification and limit our sample only to the HICs. Yet, as correctly stated by Hodgins and Saad (2020), countries may differ in terms of their economies, demographics, and geography. Future studies may choose to cluster countries depending on these factors to obtain more homogeneous samples. In this way, it will be possible to compare countries with similar characteristics, not only in terms of income, and provide unique managerial implications for each cluster.

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