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Comparative Analysis of OECD Countries in Terms of Basic Science and Technology Indicators Using Entropy and WASPAS Methods

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Abstract

Practical analysis of the policies implemented by countries successful in the field of science and technology is crucial, especially in the context of optimal policy selection for countries needing technological development. In this context, ranking the world's countries in terms of technological development is important for increasing the effectiveness of the policies to be implemented in this field. This study ranks 28 OECD countries on seven key science and technology indicators in 2022 using multi-criteria decision making (MCDM) methods. In the analysis, first, the importance of the variables was ranked based on the entropy method. Then, a ranking was made among the selected countries in terms of technological performance using the weighted aggregated sum product assessment (WASPAS) method. The findings obtained with the WASPAS method were confirmed with the additive ratio assessment (ARAS) method. Among the identified variables, the export market (share of computer, electronics and optics sector) parameter was selected as the most dominant criterion. Korea, Germany, Japan, France and the Netherlands were determined to be the best performing in terms of basic science and technology indicators. On the other hand, it can be said that Chile, Latvia, Luxembourg and Lithuania need more effective policies in terms of technology and innovation indicators. In this context, it can be suggested that the policies implemented by countries at the forefront in technological development should be a guide for other countries.

Keywords: Main science and technology indicators, OECD countries, multi-criteria decision making methods

JEL Classification: C40, O21, O32

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1. Introduction

International comparisons in economic research are often based on sector classifications such as production, employment, research and development, or foreign trade. Typical products define sectors, but many businesses categorize their main economic activity on a sectoral basis, producing various products. The production and function of these products are based on technological developments, and most products are now produced with advanced technology (Schmoch, 2008). Countries that produce with high technology-based methods have seen a significant acceleration in their economic growth. In other words, technological innovation is one of the vital elements of contemporary policymaking for both governments and companies (Smirnov and Willoughby, 2021).

Technological progress has become the main driver of economic growth for countries, regions and cities, enabling more efficient production (Hausmann and Dominguez, 2022). Technological achievements create wealth, power, opportunity and national prestige for each country. Therefore, countries are diligent in mastering technology. Governments are now aware that they can only compete on global markets and ensure national security with scientific and technological advancement. In short, the appropriate use of science and technology plays a critical role in meeting national needs (Ghorshi Nezhad *et al*., 2015).

Technological innovations support sustainable development by enabling the recovery of traditional industries, the emergence of new elements and the development of new products and production methods. Technological innovation, which contributes to the greening of the economy and digital transformation, lays the groundwork for a sustainable economic development model in coordination with the institutional innovations it fosters. With improvements in technology and innovation parameters and the development of many factors such as environmental sustainability, social welfare increases and the transition to a sustainable and inclusive future accelerates. Achievements in science and technology are the fundamental drivers of sustainable innovation (Yin *et al*., 2023; Sarpong *et al*., 2023).

One of the basic building blocks of economic development is scientific and technological progress. Technology is essential for creating wealth, improving a society's quality of life and fostering economic growth. Simply put, technology means that individuals understand and use natural resources in a way that suits their need. The application of technology for practical purposes happens gradually but represents an ongoing process. Technological applications, which reflect collective human rationality, act as engines of growth by systematically addressing human problems. However, for this to happen, emerging technological developments should become widespread. For technology to become widespread, it must be (i) flexible, manageable and inexpensive, (ii) adaptable to changing needs, (iii) technically feasible, and (iv) have the potential to create employment (Anaeto *et al*., 2016).

To achieve sustainable competitive advantage in the global arena, factors such as technological achievement capacity, creativity, diffusion of innovation and knowledge production must dominate the economy. The view that countries gain significant momentum in their economic growth due to technological development has been supported by many applied studies in the literature (Sultanuzzaman, 2019; Bahrini and Qaffas, 2019; Sharma *et al*., 2021; Jahanger *et al*., 2022). In using technology, countries make various arrangements to increase their technological achievements, access global technologies, adapt to rapid technological transformations and organize their infrastructures accordingly. When countries increase their technological capacity and performance, they benefit from global technological advantages (Incekara *et al*., 2017). Technological development also has positive effects in terms of increasing employment, raising wages and improving the access the products and services for the poor. Additionally, investing in technology facilitates the adoption of new technologies by enhancing firm capabilities and workforce productivity (Correa, 2014).

Emerging technologies such as automated production, advanced materials, microelectronics, biotechnology, nanotechnology, information technologies, environmental technologies, aviation technologies and energy technologies are significant for increasing international competition. Therefore, the formation and management of technological policies plays a critical role in transitioning from the current state to the ideal state. However, since each country has limited resources and opportunities, it is crucial to prioritize science and technology fields to achieve the goals and missions (Ghorshi Nezhad *et al*., 2015).

High-level national policy discussions and decisions regarding science and innovation policies often depend on statistical information about a country's research and development (R&D) spending levels. For this reason, the measurement of R&D expenditures holds particular importance for countries. Statistics of R&D, which serve as the main driving force of social and economic development in the long term (OECD, 2017), remain important for three main reasons.

The first reason is to reveal the size of R&D inputs (personnel and expenditures) and their distribution across sectors, industries, scientific fields and other classification categories facilitating tracking and planning of expenditures. Besides R&D statistics provide an indicator of technological change and therefore contain important information for governments concerned with economic growth and productivity. Consultants dealing with science policy, industrial policy and even general economic and social policy use these statistics extensively. R&D statistics are now an essential background element for many government programmes and provide a meaningful output for evaluating development.

The second justification is to enhance the activity of policy practitioners and other actors in the innovation system, especially in the business sector. Finally, the third fundamental justification is that measuring R&D can encourage surveyed organizations to improve their R&D management (UNESCO, 2014).

Basic science and technology indicators, which consist mainly of R&D performance indicators, provide information about the development level of countries. In this context, the present study aims to compare selected OECD countries in terms of essential information and technology indicators in 2022. Thus, according to the seven different science and technology indicators used, it aims to make policy recommendations in parallel with the policies implemented by prosperous countries by ranking them based on the comparison.

The criteria used in terms of technology development include the share of R&D expenditures in gross domestic product (GDP) (%-*GERD*), total number of researchers (*FTE*), total full-time R&D personnel (equivalent per thousand total employees – *AR-GEPER*), share of R&D expenditures of commercial enterprises in GDP (%-*BERD*), share of R&D expenditures of higher education in GDP (%-*HERD*), share of R&D expenditures of intra-state companies in GDP (%-*GOVERD*) and export market share (%-*EX*) of the computer, electronics and optics sector.

In this study, the entropy and WASPAS methods from MCDM are used to rank countries in terms of science and technology. First, the criteria are weighted with the entropy method, one of the objective criterion weighting methods. Then, the countries are ranked by science and technology indicators with the WASPAS method. Finally, the ranking values of the countries are obtained according to the different λ parameters used in the WASPAS method. Additionally, the country rankings obtained using the additive ratio assessment (ARAS) method, one of the MCDM methods, are compared with the rankings obtained from the WASPAS method.

In this context, using MCDM, the study aims to (i) make a performance measurement consisting of technology-weighted indicators for selected OECD countries, (ii) create a weighted ranking for the indicators used, (iii) determine the relative importance values of the criteria, and (iv) provide general information about the policy followed by the countries that perform successfully in terms of technology indicators.

However, there are certain limitations to the study. It does not identify sectors in which current technology and innovation are mainly used in the countries that use these indicators to achieve sustainable development and inclusive growth. Further research focusing on sectors in which the technology and innovation indicators can be more effective would provide valuable insights to strengthen policy recommendations. Additionally, determining which sectors create higher added value in terms of development of technology and innovation parameters can be a guidance for underdeveloped countries regarding these indicators.

The performance ranking in the field of science and technology using the MCDM methods can also be used to test other groups of countries. In this sense, the performance of countries with high income levels and greater R&D spending can be expected to be higher. Moreover, similar comparisons between different parameters can be made for different country groups using the same method.

2. Literature Review

In detailed research on the countries of the world, many studies have been conducted on why some countries have been much more advanced in terms of science and technology throughout history. The answer to this question began to be explained by the phenomenon known as Cardwell's law. In the early 1970s, British historian Donald Cardwell revealed the main turning points in the history of Western technology. This law attributes the success of countries in the field of science and technology to the traditional views and ideas put forward by nations, bad practices and the existence of incomplete institutions (Taylor, 2016).

There are many reasons why countries differ in their performance in science and technology. Many studies have explored this subject, focusing on the roles of the environment, institutions, infrastructure, actors and national innovation performance. These studies emphasize the division of labour, coordination and cooperation between the public sector and the private sector, and socio-cultural institutional arrangements in promoting innovation activities (Wu and Huang, 2024).

Although there are many studies on why countries differ in their science and technology performance, studies ranking countries according to their performance levels in the field of science and technology are quite limited in the literature. For this reason, to form a general perspective on the subject, this literature review includes not only studies that rank countries in terms of technology but also studies on other parameters showing developments in technology performance.

In Htun's (2019) study, which analyses countries according to information and communication technology (ICT) parameters, data collected from 63 organizations and quantitative methods were used to examine the development of ICT in Myanmar. The study showed that Myanmar is at an early stage of technological development, using ICT for daily operational activities. The study by Torkayesh and Torkayesh (2021) compared the G7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States) in terms of ICT. Using MCDM, the study found that the United States and Japan are the best-performing countries in ICT development, while countries such as Italy and Canada need to enhance their ICT policies to improve their performance.

Aiming at the selection of the most optimal renewable energy technology that can be used in the home, Ren *et al*. (2009), Ekholm *et al*. (2014), Džiugaitė-Tumėnienė *et al*. (2017), Arikan *et al*. (2017), Siksnelyte *et al*. (2020), Yang *et al*. (2018), Saleem and Ulfat (2019) also used MCDM methods. Similarly, Garfi *et al*. (2009) used these methods for a refugee camp in the Sahrawi ADR, Coban *et al*. (2018) for Istanbul specifically and Muhammad *et al*. (2021) for municipalities in Nigeria to select methods for reducing solid waste. Balezentis *et al*. (2021) used MCDM and best-worst methods (BWM) to select renewable energy heating technologies for sustainable energy policy formulation. Ali *et al*. (2020) used these methods to optimize technology selection for energy production in Bangladesh. Afran *et al*. (2021) used the methods to determine the investments needed for selecting solid waste technologies in Ghana.

Ghorshi Nezhad *et al*. (2015) used the step-wise weight assessment ratio analysis (SWARA) method to select policies for developing the nanotechnology industry in Iran, identifying sectors where nanotechnology is more effective, such as agriculture, transportation, construction, oil and gas, textile products, food industry, defence industry, health and medicine, nanoelectronics, nano energy, and environment and water. Mohagheghi and Mousavi (2019) used MCDM methods to select a high-tech project portfolio in Iran. Yücenur and Ipekçi (2021) used the SWARA and WASPAS methods to solve the site selection problem for Turkey's first offshore energy production facility. Ecer and Aycin (2022) used MCDM methods to rank the factors affecting the innovation performance of G7 countries finding that "business sophistication" is the most critical innovation indicator and the USA has the best overall ranking in terms of innovation performance.

Among the recent studies optimizing decisions using multiple decision-making methods, Ćetković *et al*. (2023) selected the best solution to improve the wastewater treatment capacity in the municipality of Dojran, North Macedonia concluding that the AHP (analytical hierarchy process) method was the most appropriate. Yagmahan and Yılmaz (2023) used TOPSIS (technique for order preference by similarity to ideal solution) and MOORA (multi-objective optimization on the basis of ratio) to determine the locations of electric vehicle charging stations (EVCS) in Turkey. Ali *et al*. (2024) used the method to rank 29 different risks and malfunctions that may occur in technological equipment. Setiawan *et al*. (2023) and Lu *et al*. (2023) used the methods to prioritize and rank energy resources for regional use. Radomska-Zalas (2023) used the WASPAS method to select the most technologically appropriate production process in manufacturing.

Examining the literature, we clearly see that MCDM methods are generally used to determine which technology is the most effective and efficient in policy determination. In other words, these methods help identify the optimal choices in preferences. However, there is a lack of studies in the literature that analyses country-specific rankings based on technological indicators for OECD countries. By using the entropy method, an objective criteria evaluation method, to weight the criteria, and the WASPAS method, which combines the weighted sum model and the weighted product model for country ranking, this study ensures reliability and accuracy of the country rankings. Additionally, the ranking values of the countries are obtained according to the different λ parameters used in the WASPAS method, and the obtained rankings are compared with the ARAS method for robustness purposes. Therefore, this study holds unique value in terms of its methodology, purpose and sample of countries analysed.

2.1 Literature gap

Successful practices for basic science and technology indicators are not implemented equally across all countries. However, it is crucial to identify which countries have taken steps in this direction through successful practices. For this reason, it is essential to identify the countries that lead in science and technology for determining effective policy choices for other countries. Despite the availability of data on the technological development of OECD countries in various databases, there is a lack of studies that reveal the contributions of these indicators to the development of OECD countries on a country-specific basis and enable comparisons between countries in terms of technology and innovation indicators. This study seeks to fill this gap by answering questions about which technologies and innovations are most effective for these countries and making comparisons between countries in terms of policy applications. The lack of studies specifically analysing OECD countries in this context highlights the unique value of this research.

3. Data and Methodology

In the present study, using the entropy and WASPAS methods, according to 2022 data, OECD countries are examined (Austria, Belgium, Chile, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Lithuania, Latvia, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and Turkey) in terms of basic science and technology parameters. For this purpose, the definitions and details of the variables obtained from the OECD database are given in Table 1. The data in the table consist of main science and technology parameters taken from the OECD database.

Table 1: Criteria, attributes and codes

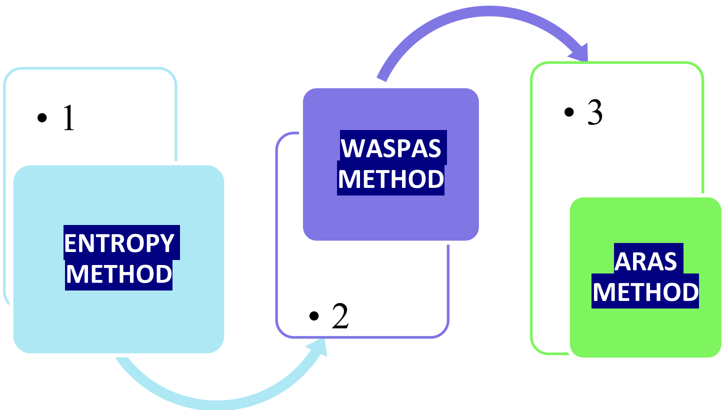
Order	Criteria	Direction	Codes
1	Share of research and development expenditures in GDP (%)	Utility (Max)	*GERD*
2	Total number of researchers	Utility (Max)	*FTE*
3	Total full-time R&D personnel (equivalent per thousand total employees)	Utility (Max)	*AR-GEPER*
4	Share of R&D expenditures of commercial enterprises in GDP (%)	Utility (Max)	*BERD*
5	Share of R&D expenditures of higher education in GDP (%)	Utility (Max)	*HERD*
6	Share of R&D expenditures of intra-state companies in GDP (%)	Utility (Max)	*GOVERD*
7	Export market share of computer, electronics and optics sector (%)	Utility (Max)	*EX*

Source: Authors' own elaboration

The indicators in Table 1 represent some of the parameters that show countries' basic knowledge and technological development. Many factors contribute to the technological development of countries. The main reason for choosing these variables is that they are the most fundamental science and technology indicators. With the help of these indicators, the trends of OECD countries in the field of science and technology can be easily seen and the changes in their performance can be compared. In addition, these indicators are highly valid parameters as they are based on country size, changes in purchasing power and various demographic criteria (OECD, 2023).

Determining which factor performs better in demonstrating technological development is particularly important for policymaking. In this context, MCDM methods are used in the analytical part of the study. This method takes into account different qualitative and quantitative criteria that need to be corrected to find the best solution. In addition, since each criterion is weighted differently during the application of the method according to its degree of importance in specific situations, it can be used effectively as the most accurate decision-making method (Taherdoost and Madanchian, 2023). With this method, the relative importance of technological indicators is determined, and it facilitates the evaluation process of countries in terms of various indicators with less complexity but reliable calculation methods (Torkayesh and Torkayesh, 2021). The methods applied in the context of MCDM in the context of OECD countries focusing on the context of technology and innovation indicators, which are the main purpose of the study, are illustrated in Figure 1.

Figure 1: Conceptual framework flow chart



Source: Authors' own elaboration

3.1 Entropy method

The concept of entropy, known as a criterion of disorder and dispersion in thermodynamics, was first introduced by Rudolf Clausius in 1865. Entropy, the second law of thermodynamics, briefly states that all systems left to their own devices and natural conditions in the universe will lead to disorder and deterioration over time.

This concept was given a different usage by Shannon (1948) and became known as information entropy. According to information theory, entropy measures uncertainty about random variables (Bakır and Atalık, 2018; Zhang *et al*., 2011). The entropy method objectively determines the weights of the criteria by considering the values of the alternatives in terms of the criteria, without the need for the subjective judgments of the decision-makers in determining the importance level of the criteria (Karaatlı, 2016). The stages of the entropy method are as follows (Zhu, 2020; Arsu, 2021):

Stage 1: The decision matrix is created. The decision matrix is denoted as **D**, which consists of x_{ij} (the value of the i-th alternative according to the j-th criterion). The decision matrix is expressed by Equation (1).

$$\mathbf{D} = [x_{ij}]_{mxn} \tag{1}$$

Here, m is the number of alternatives and n is the number of criteria.

Stage 2: The values taken from different units are normalized at this stage. With the normalization process, each value is standardized to take a value between [0, 1]. Equation (2) is used for normalization.

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \qquad \forall i, j \tag{2}$$

Stage 3: Entropy values (e_j) and differentiation degrees (d_j) related to the criteria are found at this stage. Equation (3) is used for entropy values (e_j), and Equation (4) is used for degrees of differentiation (d_j).

$$3.\ \ e_{ij} = -\frac{1}{\ln(m)} \sum_{j=1}^{n} [p_{ij} \times \ln(p_{ij})] \qquad \forall i, j \tag{3}$$

$$d_j = 1 - e_{ij} \tag{4}$$

Stage 4: In this final stage, the criterion weights are determined. The criterion weights are obtained by Equation (5).

$$w_{ij} = \frac{d_j}{\sum_{j=1}^{n} d_j} \qquad \forall j \tag{5}$$

In this method, the criterion with a higher weight calculated in terms of decision making is more critical compared to other criteria, whereas a criterion with a lower weight is more insignificant (Isık, 2019).

3.2 WASPAS method

The WASPAS method integrates the weighted sum model (WSM) and the weighted product model (WPM). By using these two methods together, it aims to correctly rank the decision alternatives (Aycin, 2020, p. 309). The method was developed by Zavadskas *et al*. (2012) and has been used frequently in recent years because it provides more accurate results and rankings than other MCDM methods (Chakraborty *et al*., 2015, p. 1; Cakir *et al*., 2018, p. 6).

The WASPAS method uses the criteria-based performance values and criterion weights of alternatives in solving the problem. It aims to achieve high consistency in the estimation by optimizing the weighted integrated function (Adali and Isık, 2017, p. 66). The stages of the WASPAS method are as follows (Aycin, 2020, pp. 309–310; Chakraborty and Zavadskas, 2014, p. 3):

Stage 1: At this stage, the decision matrix is created. The decision matrix is represented by **X**, which consists of x_{ij} (the value of the *i*-th alternative according to the *j*-th criterion). The decision matrix is expressed by Equation (6).

$$\mathbf{X} = [x_{ij}]_{mxn} \tag{6}$$

Here, m is the number of alternatives and n is the number of criteria.

Stage 2: The values taken from different units are normalized at this stage. With the normalization process, each value is standardized to take a value between [0, 1]. Equation (7) is used for normalization and benefit-oriented criteria, and Equation (8) is used for cost-oriented criteria.

$$x_{ij}^{*} = \frac{x_{ij}}{max_i\left(x_{ij}\right)} \tag{7}$$

$$x_{ij}^{*} = \frac{min_i(x_{ij})}{x_{ij}} \tag{8}$$

Stage 3: Relative importance values are calculated using the weighted sum method. The relative importance values of alternatives are calculated using the criterion weights obtained by the entropy method in Equation (9).

$$Q_i^{(1)} = \sum_{j=1}^{n} x_{ij}^{*} \times w_j \tag{9}$$

Stage 4: Relative importance values are calculated according to the weighted product method. Using the criterion weights obtained by the entropy method in Equation (10), the relative importance values of the alternatives are calculated.

$$Q_i^{(2)} = \prod_{j=1}^{n} (x_{ij}^{*})^{w_j} \tag{10}$$

Stage 5: The weighted common general criterion values (Q_i) for the weighted sum and weighted product models are calculated with the help of Equation (11).

$$Q_i = 0.5Q_i^{(1)} + 0.5Q_i^{(2)} = 0.5 \times \sum_{j=1}^{n} x_{ij}^{*} \times w_j + 0.5 \times \prod_{j=1}^{n} (x_{ij}^{*})^{w_j} \tag{11}$$

Stage 6: The relative importance values of the alternatives are calculated with the help of Equation (12).

$$Q_i = \lambda \times Q_i^{(1)} + \left(1-\lambda\right) \times Q_i^{(2)} = \lambda \times \sum_{j=1}^{n} x_{ij}^{*} \times w_j + \left(1-\lambda\right) \times \prod_{j=1}^{n} (x_{ij}^{*})^{w_j} \tag{12}$$

4. Findings

In the first stage of the analysis, criteria were weighted according to the order of importance among the basic science and technology indicators determined by the entropy method. In the second stage, based on the determined weighting, selected OECD countries were ranked according to their technological performance with the WASPAS method. Additionally, the findings obtained by the WASPAS method were verified with the ARAS method, which is also one of the MCDM methods.

4.1 Weighting criteria with entropy method

The weighting of the criteria using the entropy method was carried out with the following steps.

Stage 1: Decision matrix

The decision matrix consists of alternatives (countries) and values of criteria (*GERD*, *FTE*, *AR-GEPER*, *BERD*, *HERD*, *GOVERD* and *EX*) associated with these alternatives, as shown in Table 2.

Table 2: Decision matrix

Countries/criteria	*GERD*	*FTE*	*AR-GEPER*	*BERD*	*HERD*	*GOVERD*	*EX*
Austria	3.22	51,892	18.37	2.24	0.72	0.24	0.32
Belgium	3.38	64,053	19.79	2.50	0.57	0.28	0.38
Chile	0.34	9,961.87	2.18	0.12	0.16	0.04	0.01
Czechia	1.99	44,205.96	15.17	1.21	0.43	0.34	1.33
Denmark	2.97	44,553	20.87	1.83	1.03	0.10	0.26
Estonia	1.75	5,097.80	10.18	0.96	0.59	0.17	0.08
Finland	2.91	41,707.10	20.40	1.95	0.72	0.22	0.13
France	2.35	321,549.64	16.63	1.55	0.47	0.28	1.09
Germany	3.13	450,796.44	16.34	2.09	0.59	0.46	4.54
Greece	1.51	42,948.82	12.89	0.70	0.48	0.32	0.06
Hungary	1.60	42,099	12.78	1.22	0.21	0.16	0.65
Ireland	1.08	23,929	14.61	0.75	0.28	0.04	0.73
Italy	1.51	156,988.90	13.70	0.93	0.35	0.20	0.63
Japan	3.27	689,889	13.35	2.58	0.38	0.27	3.32
Korea	4.81	446,738.85	20.27	3.81	0.43	0.49	5.68
Lithuania	1.17	10,182.90	10.58	0.56	0.42	0.18	0.07
Latvia	0.71	4,072	7.47	0.22	0.36	0.13	0.06
Luxembourg	1.07	2,936.50	11.76	0.55	0.25	0.27	0.02
Mexico	0.30	44,965.89	1.93	0.06	0.15	0.08	2.70
Netherlands	2.32	102,077	17.41	1.55	0.65	0.13	2.66
Norway	2.28	36,316	17.53	1.24	0.76	0.28	0.09
Poland	1.39	124,599.70	10.57	0.87	0.48	0.03	0.78
Portugal	1.62	53,174.27	13.59	0.92	0.58	0.08	0.14
Slovakia	0.91	17,276.40	9.34	0.49	0.24	0.18	0.42
Slovenia	2.14	10,845	16.19	1.57	0.26	0.29	0.04
Spain	1.41	145,371.50	11.87	0.78	0.37	0.25	0.28
Sweden	3.49	80,089	18.86	2.52	0.81	0.15	0.47
Turkey	1.09	149,731.12	7.53	0.71	0.31	0.07	0.08

Source: Authors' own calculations

Stage 2: Normalization of decision matrix

Normalized values (Table 3) [0, 1] are obtained by dividing each value in the decision matrix by the total value in its column (Equation (2)).

Table 3: Normalized decision matrix

Countries/criteria	*GERD*	*FTE*	*AR-GEPER*	*BERD*	*HERD*	*GOVERD*	*EX*
Austria	0.05779	0.01613	0.04807	0.06131	0.05513	0.04220	0.01171
Belgium	0.06066	0.01990	0.05178	0.06841	0.04371	0.04901	0.01412
Chile	0.00610	0.00310	0.00569	0.00328	0.01229	0.00647	0.00027
Czechia	0.03571	0.01374	0.03969	0.03319	0.03291	0.05918	0.04941
Denmark	0.05330	0.01384	0.05461	0.05013	0.07877	0.01780	0.00965
Estonia	0.03141	0.00158	0.02665	0.02638	0.04509	0.02991	0.00281
Finland	0.05223	0.01296	0.05338	0.05350	0.05487	0.03862	0.00475
France	0.04218	0.09992	0.04352	0.04258	0.03637	0.04847	0.04049
Germany	0.05617	0.14008	0.04277	0.05718	0.04495	0.07958	0.16796
Greece	0.02710	0.01335	0.03372	0.01907	0.03677	0.05649	0.00209
Hungary	0.02872	0.01308	0.03343	0.03349	0.01589	0.02756	0.02400
Ireland	0.01938	0.00744	0.03824	0.02069	0.02137	0.00771	0.02696
Italy	0.02710	0.04878	0.03586	0.02559	0.02674	0.03469	0.02345
Japan	0.05869	0.21438	0.03495	0.07061	0.02938	0.04712	0.12285
Korea	0.08632	0.13882	0.05305	0.10437	0.03314	0.08460	0.21033
Lithuania	0.02100	0.00316	0.02768	0.01544	0.03254	0.03139	0.00257
Latvia	0.01274	0.00127	0.01954	0.00600	0.02723	0.02313	0.00233
Luxembourg	0.01920	0.00091	0.03076	0.01506	0.01915	0.04732	0.00063
Mexico	0.00538	0.01397	0.00504	0.00176	0.01160	0.01357	0.09985
Netherlands	0.04164	0.03172	0.04556	0.04238	0.04951	0.02265	0.09854
Norway	0.04092	0.01129	0.04587	0.03393	0.05805	0.04928	0.00324
Poland	0.02495	0.03872	0.02767	0.02386	0.03713	0.00475	0.02875
Portugal	0.02907	0.01652	0.03555	0.02526	0.04466	0.01391	0.00534
Slovakia	0.01633	0.00537	0.02444	0.01351	0.01829	0.03123	0.01551
Slovenia	0.03841	0.00337	0.04238	0.04306	0.02010	0.05124	0.00165
Spain	0.02531	0.04517	0.03105	0.02142	0.02872	0.04266	0.01027
Sweden	0.06263	0.02489	0.04936	0.06921	0.06192	0.02667	0.01740
Turkey	0.01956	0.04653	0.01970	0.01934	0.02372	0.01280	0.00308

Source: Authors' own calculations

Stage 3: Finding entropy values (e_j) and differentiation degrees (d_j) related to criteria

In order to find the entropy values (e_j) of the criteria, first, each value in the normalized decision matrix is multiplied by its natural logarithm. Then, the entropy values are calculated using the values obtained in Equation (3). Here, *m* represents the number of alternatives (countries) and equals 28. Finally, the degrees of differentiation are determined using Equation (4).

Table 4: Entropy values (e_j) and degrees of differentiation (d_j)

Countries/criteria	*GERD*	*FTE*	*AR-GEPER*	*BERD*	*HERD*	*GOVERD*	*EX*
Austria	−0.16475	−0.06656	−0.14589	−0.17117	−0.15976	−0.13358	−0.05209
Belgium	−0.17000	−0.07796	−0.15331	−0.18348	−0.13681	−0.14781	−0.06014
Chile	−0.03111	−0.01789	−0.02942	−0.01878	−0.05407	−0.03262	−0.00224
Czechia	−0.11901	−0.05890	−0.12807	−0.11302	−0.11236	−0.16732	−0.14860
Denmark	−0.15627	−0.05925	−0.15878	−0.15004	−0.20017	−0.07172	−0.04477
Estonia	−0.10869	−0.01021	−0.09660	−0.09589	−0.13973	−0.10498	−0.01651
Finland	−0.15418	−0.05632	−0.15642	−0.15665	−0.15928	−0.12567	−0.02542
France	−0.13352	−0.23016	−0.13641	−0.13440	−0.12052	−0.14671	−0.12985
Germany	−0.16174	−0.27534	−0.13481	−0.16363	−0.13945	−0.20141	−0.29964
Greece	−0.09778	−0.05761	−0.11430	−0.07550	−0.12145	−0.16233	−0.01289
Hungary	−0.10195	−0.05673	−0.11361	−0.11376	−0.06581	−0.09897	−0.08951
Ireland	−0.07643	−0.03645	−0.12481	−0.08025	−0.08218	−0.03750	−0.09741
Italy	−0.09778	−0.14734	−0.11935	−0.09380	−0.09685	−0.11661	−0.08800
Japan	−0.16641	−0.33015	−0.11721	−0.18715	−0.10364	−0.14395	−0.25759
Korea	−0.21146	−0.27411	−0.15579	−0.23586	−0.11290	−0.20894	−0.32792
Lithuania	−0.08112	−0.01821	−0.09928	−0.06439	−0.11147	−0.10864	−0.01534
Latvia	−0.05559	−0.00844	−0.07690	−0.03068	−0.09813	−0.08713	−0.01412
Luxembourg	−0.07590	−0.00639	−0.10710	−0.06319	−0.07576	−0.14436	−0.00462
Mexico	−0.02813	−0.05967	−0.02667	−0.01114	−0.05171	−0.05835	−0.23006
Netherlands	−0.13235	−0.10946	−0.14072	−0.13397	−0.14880	−0.08580	−0.22835
Norway	−0.13078	−0.05061	−0.14136	−0.11479	−0.16524	−0.14835	−0.01856
Poland	−0.09208	−0.12589	−0.09927	−0.08913	−0.12228	−0.02541	−0.10203
Portugal	−0.10286	−0.06780	−0.11862	−0.09292	−0.13882	−0.05948	−0.02792
Slovakia	−0.06720	−0.02806	−0.09071	−0.05814	−0.07319	−0.10825	−0.06463
Slovenia	−0.12519	−0.01919	−0.13396	−0.13543	−0.07853	−0.15224	−0.01057
Spain	−0.09304	−0.13991	−0.10781	−0.08233	−0.10197	−0.13456	−0.04704
Sweden	−0.17353	−0.09192	−0.14851	−0.18484	−0.17226	−0.09665	−0.07051
Turkey	−0.07696	−0.14274	−0.07736	−0.07632	−0.08876	−0.05578	−0.01781
Total	−3.18583	−2.6232635	−3.25303	−3.11065	−3.23189	−3.1651	−2.50412
ln(*m*)	0.30010						
E_j	0.956073	0.78724566	0.97624	0.933512	0.969895	0.949852	0.751491
D_j	0.043927	0.21275434	0.02376	0.066488	0.030105	0.050148	0.248509

Source: Authors' own calculations

Stage 4: Finding entropy criterion weights

Each degree of differentiation value is divided by the total differentiation value (Equation (5)) to obtain the criterion weights.

Table 5: Criterion weights

Criteria	*GERD*	*FTE*	*AR-GEPER*	*BERD*	*HERD*	*GOVERD*	*EX*
Weight (w_j)	0.06501	0.31487	0.03516	0.09840	0.04455	0.07422	0.36778

Source: Authors' own calculations

As seen in Table 5, the essential criterion according to the entropy criterion weighting method is *EX* (0.36778). Following this criterion, the *FTE*, *BERD*, *GOVERD*, *GERD*, *HERD* and *AR-GEPER* criteria are ranked in descending order of importance. This hierarchy affects the export technology performance of high-tech products more for selected OECD countries. The export factor is a factor that is affected by all technology-based developments. In other words, the export parameter is a long-term output of technology-based indicators. Therefore, this parameter holds predominant significance in the criterion weight part.

4.2 Ranking alternatives (countries) with WASPAS method

The process of ranking the countries in terms of performance indicators with the WASPAS method was carried out in the following stages.

Stage 1: Decision matrix

The decision matrix consists of alternatives (countries) and values of criteria (*GERD*, *FTE*, *AR-GEPER*, *BERD*, *HERD*, *GOVERD* and *EX*) related to alternatives. The decision matrix is given in Table 6. All the criteria are utility-oriented criteria.

Stage 2: Normalization of decision matrix

Normalized [0, 1] values are obtained by dividing (Equation (7)) each value in the decision matrix by the largest value in its column (because the benefit direction is criteria).

Table 6: Normalized decision matrix

Countries/criteria	*GERD*	*FTE*	*AR-GEPER*	*BERD*	*HERD*	*GOVERD*	*EX*
Austria	0.669	0.075	0.880	0.587	0.700	0.499	0.056
Belgium	0.703	0.093	0.948	0.655	0.555	0.579	0.067
Chile	0.071	0.014	0.104	0.031	0.156	0.076	0.001
Czechia	0.414	0.064	0.727	0.318	0.418	0.700	0.235
Denmark	0.617	0.065	1.000	0.480	1.000	0.210	0.046
Estonia	0.364	0.007	0.488	0.253	0.572	0.354	0.013
Finland	0.605	0.060	0.977	0.513	0.697	0.456	0.023
France	0.489	0.466	0.797	0.408	0.462	0.573	0.193
Germany	0.651	0.653	0.783	0.548	0.571	0.941	0.799
Greece	0.314	0.062	0.617	0.183	0.467	0.668	0.010
Hungary	0.333	0.061	0.612	0.321	0.202	0.326	0.114
Ireland	0.225	0.035	0.700	0.198	0.271	0.091	0.128
Italy	0.314	0.228	0.657	0.245	0.340	0.410	0.111
Japan	0.680	1.000	0.640	0.677	0.373	0.557	0.584
Korea	1.000	0.648	0.971	1.000	0.421	1.000	1.000
Lithuania	0.243	0.015	0.507	0.148	0.413	0.371	0.012
Latvia	0.148	0.006	0.358	0.057	0.346	0.273	0.011
Luxembourg	0.222	0.004	0.563	0.144	0.243	0.559	0.003
Mexico	0.062	0.065	0.092	0.017	0.147	0.160	0.475
Netherlands	0.482	0.148	0.834	0.406	0.629	0.268	0.468
Norway	0.474	0.053	0.840	0.325	0.737	0.583	0.015
Poland	0.289	0.181	0.507	0.229	0.471	0.056	0.137
Portugal	0.337	0.077	0.651	0.242	0.567	0.164	0.025
Slovakia	0.189	0.025	0.448	0.129	0.232	0.369	0.074
Slovenia	0.445	0.016	0.776	0.413	0.255	0.606	0.008
Spain	0.293	0.211	0.569	0.205	0.365	0.504	0.049
Sweden	0.726	0.116	0.904	0.663	0.786	0.315	0.083
Turkey	0.227	0.217	0.361	0.185	0.301	0.151	0.015

Source: Authors' own calculations

Stage 3: Relative significance values by weighted sum method

The criterion weights found according to the entropy method are used in Equation (9), and the relative importance values ($Q_i^{(1)}$) are calculated according to the weighted sum method.

Table 7: Relative importance values of countries by weighted sum method

Countries/criteria	*GERD*	*FTE*	*AR-GEPER*	*BERD*	*HERD*	*GOVERD*	*EX*	$Q_i^{(1)}$
Austria	0.044	0.024	0.031	0.058	0.031	0.037	0.020	0.245
Belgium	0.046	0.029	0.033	0.064	0.025	0.043	0.025	0.265
Chile	0.005	0.005	0.004	0.003	0.007	0.006	0.000	0.029
Czechia	0.027	0.020	0.026	0.031	0.019	0.052	0.086	0.261
Denmark	0.040	0.020	0.035	0.047	0.045	0.016	0.017	0.220
Estonia	0.024	0.002	0.017	0.025	0.026	0.026	0.005	0.125
Finland	0.039	0.019	0.034	0.050	0.031	0.034	0.008	0.216
France	0.032	0.147	0.028	0.040	0.021	0.043	0.071	0.381
Germany	0.042	0.206	0.028	0.054	0.025	0.070	0.294	0.718
Greece	0.020	0.020	0.022	0.018	0.021	0.050	0.004	0.154
Hungary	0.022	0.019	0.022	0.032	0.009	0.024	0.042	0.169
Ireland	0.015	0.011	0.025	0.020	0.012	0.007	0.047	0.136
Italy	0.020	0.072	0.023	0.024	0.015	0.030	0.041	0.226
Japan	0.044	0.315	0.023	0.067	0.017	0.041	0.215	0.721
Korea	0.065	0.204	0.034	0.098	0.019	0.074	0.368	0.862
Lithuania	0.016	0.005	0.018	0.015	0.018	0.028	0.004	0.103
Latvia	0.010	0.002	0.013	0.006	0.015	0.020	0.004	0.069
Luxembourg	0.014	0.001	0.020	0.014	0.011	0.042	0.001	0.103
Mexico	0.004	0.021	0.003	0.002	0.007	0.012	0.175	0.223
Netherlands	0.031	0.047	0.029	0.040	0.028	0.020	0.172	0.367
Norway	0.031	0.017	0.030	0.032	0.033	0.043	0.006	0.191
Poland	0.019	0.057	0.018	0.022	0.021	0.004	0.050	0.191
Portugal	0.022	0.024	0.023	0.024	0.025	0.012	0.009	0.140
Slovakia	0.012	0.008	0.016	0.013	0.010	0.027	0.027	0.114
Slovenia	0.029	0.005	0.027	0.041	0.011	0.045	0.003	0.161
Spain	0.019	0.066	0.020	0.020	0.016	0.037	0.018	0.197
Sweden	0.047	0.037	0.032	0.065	0.035	0.023	0.030	0.270
Turkey	0.015	0.068	0.013	0.018	0.013	0.011	0.005	0.144

Source: Authors' own calculations

Stage 4: Relative significance values according to weighted product method

The criterion weights determined by the entropy method are used in Equation (10), and the relative importance values ($Q_i^{(2)}$) are calculated according to the weighted product method.

Table 8: Relative significance values by weighted product method

Countries/criteria	*GERD*	*FTE*	*AR-GEPER*	*BERD*	*HERD*	*GOVERD*	*EX*	$Q_i^{(2)}$
Austria	0.974	0.443	0.996	0.949	0.984	0.950	0.346	0.131693
Belgium	0.977	0.473	0.998	0.959	0.974	0.960	0.370	0.153346
Chile	0.842	0.263	0.924	0.712	0.921	0.826	0.087	0.009604
Czechia	0.944	0.421	0.989	0.893	0.962	0.974	0.587	0.193075
Denmark	0.969	0.422	1.000	0.930	1.000	0.891	0.322	0.109109
Estonia	0.936	0.213	0.975	0.873	0.975	0.926	0.204	0.031405
Finland	0.968	0.413	0.999	0.936	0.984	0.943	0.248	0.086204
France	0.955	0.786	0.992	0.916	0.966	0.960	0.546	0.344784
Germany	0.972	0.875	0.991	0.943	0.975	0.995	0.921	0.71035
Greece	0.927	0.417	0.983	0.846	0.967	0.970	0.183	0.055347
Hungary	0.931	0.415	0.983	0.894	0.931	0.920	0.450	0.130796
Ireland	0.907	0.347	0.988	0.853	0.944	0.837	0.470	0.098389
Italy	0.927	0.627	0.985	0.871	0.953	0.936	0.446	0.19875
Japan	0.975	1.000	0.984	0.962	0.957	0.957	0.821	0.694629
Korea	1.000	0.872	0.999	1.000	0.962	1.000	1.000	0.838264
Lithuania	0.912	0.265	0.976	0.829	0.961	0.929	0.198	0.0346
Latvia	0.883	0.199	0.965	0.755	0.954	0.908	0.191	0.021124
Luxembourg	0.907	0.179	0.980	0.827	0.939	0.958	0.118	0.013947
Mexico	0.835	0.423	0.920	0.669	0.918	0.873	0.760	0.132515
Netherlands	0.954	0.548	0.994	0.915	0.980	0.907	0.757	0.319356
Norway	0.953	0.396	0.994	0.895	0.986	0.961	0.215	0.068492
Poland	0.922	0.583	0.976	0.865	0.967	0.808	0.481	0.170691
Portugal	0.932	0.446	0.985	0.870	0.975	0.875	0.259	0.078624
Slovakia	0.897	0.313	0.972	0.818	0.937	0.929	0.383	0.074533
Slovenia	0.949	0.270	0.991	0.917	0.941	0.963	0.168	0.03553
Spain	0.923	0.612	0.980	0.856	0.956	0.950	0.329	0.142004
Sweden	0.979	0.508	0.996	0.960	0.989	0.918	0.400	0.172771
Turkey	0.908	0.618	0.965	0.847	0.948	0.869	0.212	0.079947

Source: Authors' own calculations

Stage 5: Calculating and ranking common general criterion values

At this stage, with the help of Equation (11), both methods (weighted sum and weighted product) are integrated and evaluated. The weighted common general criterion value (Q_i) is calculated, and the performance ranking of the alternatives (countries) is determined according to the largest common general criterion value (Table 9).

Table 9: Common general criterion value and ranking

Countries	Q_i	Ranking	Countries	Q_i	Ranking
Austria	0.188	10	**Korea**	0.850	1
Belgium	0.209	9	**Lithuania**	0.069	25
Chile	0.019	28	**Latvia**	0.045	27
Czechia	0.227	6	**Luxembourg**	0.059	26
Denmark	0.165	14	**Mexico**	0.178	12
Estonia	0.078	24	**Netherlands**	0.343	5
Finland	0.151	15	**Norway**	0.130	17
France	0.363	4	**Poland**	0.181	11
Germany	0.714	2	**Portugal**	0.109	20
Greece	0.105	21	**Slovakia**	0.094	23
Hungary	0.150	16	**Slovenia**	0.098	22
Ireland	0.117	18	**Spain**	0.170	13
Italy	0.212	8	**Sweden**	0.221	7
Japan	0.708	3	**Turkey**	0.112	19

Source: Authors' own calculations

As seen in Table 9, Korea is the country with the best performance in basic science and technology. It is followed by Germany, Japan, France and the Netherlands. The rankings in Table 9 are based on the λ parameter value in Equation (12) as 0.5. Different rankings can be obtained with different λ parameter values.

Stage 6: Sorting by different λ parameter values

Using Equation (12), different rankings can be obtained according to different λ parameter values. Rankings for $\lambda = 0$, $\lambda = 0.25$, $\lambda = 0.75$ and $\lambda = 1$ are given in Table 10.

Table 10: Ranking of countries by different λ parameter values

	λ = 0		λ = 0.25		λ = 0.75		λ = 1	
Countries	**0**	**Ranking**	**0.25**	**Ranking**	**0.75**	**Ranking**	**1**	**Ranking**
Austria	0.132	13	0.160	11	0.216	10	0.245	9
Belgium	0.153	10	0.181	9	0.237	8	0.265	7
Chile	0.010	28	0.014	28	0.024	28	0.029	28
Czechia	0.193	7	0.210	6	0.244	7	0.261	8
Denmark	0.109	15	0.137	15	0.192	12	0.220	12
Estonia	0.031	25	0.055	24	0.101	24	0.125	23
Finland	0.086	17	0.119	16	0.184	14	0.216	13
France	0.345	4	0.354	4	0.372	4	0.381	4
Germany	0.710	2	0.712	2	0.716	2	0.718	3
Greece	0.055	22	0.080	22	0.129	19	0.154	19
Hungary	0.131	14	0.140	14	0.159	17	0.169	17
Ireland	0.098	16	0.108	17	0.126	21	0.136	22
Italy	0.199	6	0.206	7	0.219	9	0.226	10
Japan	0.695	3	0.701	3	0.714	3	0.721	2
Korea	0.838	1	0.844	1	0.856	1	0.862	1
Lithuania	0.035	24	0.052	25	0.086	25	0.103	25
Latvia	0.021	26	0.033	27	0.057	27	0.069	27
Luxembourg	0.014	27	0.036	26	0.081	26	0.103	26
Mexico	0.133	12	0.155	13	0.200	11	0.223	11
Netherlands	0.319	5	0.331	5	0.355	5	0.367	5
Norway	0.068	21	0.099	18	0.160	16	0.191	16
Poland	0.171	9	0.176	10	0.186	13	0.191	15
Portugal	0.079	19	0.094	20	0.124	22	0.140	21
Slovakia	0.075	20	0.084	21	0.104	23	0.114	24
Slovenia	0.036	23	0.067	23	0.130	18	0.161	18
Spain	0.142	11	0.156	12	0.183	15	0.197	14
Sweden	0.173	8	0.197	8	0.245	6	0.270	6
Turkey	0.080	18	0.096	19	0.128	20	0.144	20

Source: Authors' own calculations

As can be seen, the performance rankings of the countries change according to different λ values. In the case of $\lambda = 0$, the WASPAS method produces results and rankings with the weighted product method (WPM). In the case of $\lambda = 1$, the WASPAS method gives results and rankings with the WSM. The ranking of the top 5 countries according to different λ parameter values is given in Table 11.

Table 11: Ranking of top 5 countries by different λ parameter values

	λ = 0	λ = 0.25	λ = 0.50	λ = 0.75	λ = 1
Countries	**Ranking**	**Ranking**	**Ranking**	**Ranking**	**Ranking**
France	4	4	4	4	4
Germany	2	2	2	2	3
Japan	3	3	3	3	2
Korea	1	1	1	1	1
Netherlands	5	5	5	5	5

Source: Authors' own calculations

As seen in Table 11, the performance rankings of the top 5 most essential countries according to different λ values did not change. Only for $\lambda = 1$ are Germany and Japan swapped.

The performance ranking of the countries was also assessed using the ARAS (additive ratio assessment) method, which is one of the MCDM methods. The ranking obtained by the ARAS method is given in Table 12.

Table 12: Ranking of countries by ARAS method

Countries	Ranking	Countries	Ranking
Austria	12	**Korea**	1
Belgium	10	**Lithuania**	25
Chile	28	**Latvia**	27
Czechia	7	**Luxembourg**	26
Denmark	14	**Mexico**	6
Estonia	24	**Netherlands**	5
Finland	15	**Norway**	18
France	4	**Poland**	11
Germany	3	**Portugal**	21
Greece	20	**Slovakia**	23
Hungary	16	**Slovenia**	22
Ireland	19	**Spain**	13
Italy	8	**Sweden**	9
Japan	2	**Turkey**	17

Source: Authors' own calculations

When Table 12 is examined, it is evident that the rankings obtained by the ARAS method are similar to those obtained by the WASPAS method. In the ARAS ranking, the five countries with the most crucial performance remained the same. Spearman's ranking correlation coefficients between the rankings obtained by the WASPAS method according to different λ values and the rankings obtained by the ARAS method are 0.972 for $\lambda = 0$; 0.978 for $\lambda = 0.25$; 0.985 for $\lambda = 0.50$; 0.974 for $\lambda = 0.75$; and 0.966 for $\lambda = 1$. These results indicate a close relationship between the two methods in terms of rankings with the strongest correlation occurring at $\lambda = 0.50$. Additionally, all the correlation coefficients were significant at the 1% significance level.

5. Discussion

In this section, we discuss possible reasons for the empirical findings. According to the analysis, the high and significant coefficients indicate a solid and consistent relationship between the ranking methods. South Korea, Germany, Japan, France and the Netherlands were the top five countries in the rankings. However, it is evident that the technological performance of Chile, Latvia, Luxembourg and Lithuania is lower compared to other countries in the sample. The analysis shows that countries with high per capita income levels are at the forefront of science and technology. This can be attributed to the high share of R&D expenditures in their budgets, which supports technology development. Many developed countries demonstrate successful policies in this field through substantial budget allocations to R&D expenditures. South Korea, which ranks the highest in our analysis, is known for allocating the highest share of its budget to R&D in science and technology worldwide (Statista, 2023; Reardon, 2023). Korea's top ranking is due to its technology application and an innovation-oriented growth model. Since the 1980s, South Korea has experienced rapid growth, setting an example for other developing countries with its superior technological and scientific capabilities and active, continuous R&D activities. Policymakers in South Korea have shifted from an industrial strategy to a technology strategy since the 1980s. This shift has resulted in a technology development process involving substantial private sector contributions to the economy and a strong emphasis on R&D expenditures (Tunçsiper and Fırat, 2016).

South Korea has been selective in acquiring technology. Before 1980, the focus was on importing and imitating foreign technology. After 1980, the focus shifted to acquiring, adapting and specializing in foreign technology while developing necessary institutional mechanisms. The domestic development of traditional technologies, support for technology transfer and infrastructure investments have driven South Korea's technological advancement (Calısır and Gulmez, 2010). With cooperation and development plans supported by government and business networks, South Korea has rapidly disseminated technology and now competes with the world's leading countries with high-value market products (Keskin, 2021). These achievements can serve as a policy model for countries underdeveloped in science and technology.

The development of public-private partnerships for technology development is important for increasing innovation and technology diffusion potential, as successfully implemented by the Netherlands and France. Germany and Japan, among the top five countries in the analysis, consistently perform well in developing new products, processes, services and systems. Additionally, the Netherlands achieves successful results in technology diffusion indicators (OECD, 2007).

Another finding of the study is that high-tech product exports are the most dominant indicator among the selected parameters. This can be interpreted as one of the important determinants of technological performance. Success in exporting high-tech products is indicative of a country's advanced knowledge and technological capabilities. Providing faster access to new information through ICT makes high-tech production widespread. This finding aligns with those of Andersson and Ejermo (2008), Özsoy *et al*. (2022), Panda and Sharma (2020).

6. Conclusions and Policy Implications

This study utilized the entropy, WASPAS and ARAS methods (MCDM methods) to rank 28 OECD countries according to their performance in seven different fundamental science and technology indicators for the year 2022. Initially, the weight of the criteria was determined using the entropy method. The entropy criterion weighting indicated that the most influential criterion for the technological performance of OECD countries in 2022 was high-tech product exports (*EX*). This suggests a positive relationship between countries' specialization in the exports of high-tech products and science and technology performance.

Subsequently, the countries were ranked using the WASPAS method according to the weighted criteria. The ranking values were also obtained using different λ parameters in the WASPAS method and these rankings were compared with the ARAS method for validation. Spearman's ranking correlation coefficients between the WASPAS and ARAS rankings were found to be very high and significant. The analysis revealed that South Korea, Germany, Japan, France and the Netherlands are the top five countries while Chile, Latvia, Luxembourg and Lithuania lag behind. These findings suggest that countries underdeveloped in science and technology should make progress by emulating the policies implemented in the leading countries.

Other OECD countries should increase their R&D expenditures, as this is widely accepted to positively affect various elements of innovation and science. Countries should focus on technology in their development policies and ensure that statistical choices provide optimal benefits to the country's economy. State-industry cooperation will increase the diffusion rate of technological developments. Therefore, it is essential to systematically transform science and technology into economic and social benefits at this stage.

It is also important to foster harmony between households, producers and decision-makers in processes based on science, technology and innovation. Furthermore, development in sectors providing cost-based advantages for future technological advancement is crucial. R&D expenditures, particularly those enhancing energy efficiency and sustainable development, should be prioritized.

As a result, the analysis highlighted that high-tech product exports were a dominant parameter in the performance of countries in science and technology. This indicates that increases in high-tech product exports should be supported. Therefore, practices that support a labour market with high human capital and related markets, aided by tax incentives, should be promoted to create added value.

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