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Clustering Analysis on Sustainable Development Goal Indicators for Forty-Five Asian Countries

Anuradha Mathrani *, Jian Wang, Ding Li and Xuanzhen Zhang

School of Mathematical and Computational Sciences, Massey University, Auckland 0632, New Zealand
* Correspondence: a.s.mathrani@massey.ac.nz; Tel.: +64-9-2136132

Abstract: This paper draws upon the United Nations 2022 data report on the achievement of Sustainable Development Goals (SDGs) across the following four dimensions: economic, social, environmental and institutional. Ward's method was applied to obtain clustering results for forty-five Asian countries to understand their level of progress and overall trends in achieving SDGs. We identified varying degrees of correlation between the four dimensions. The results show that East Asian countries performed poorly in the economic dimension, while some countries in Southeast Asia and Central and West Asia performed relatively well. Regarding social and institutional dimensions, the results indicate that East and Central Asian countries performed relatively better than others. Finally, in the environmental dimension, West and South Asian countries showed better performance than other Asian countries. The insights gathered from this study can inform policymakers of these countries about their own country's position in achieving SDGs in relation to other Asian countries, as they work towards establishing strategies for improving their sustainable development targets.

Keywords: cluster analysis; sustainable development goals; Asian countries; economic; social; environmental; institutional

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1. Introduction

The term 'sustainable development' endorsed in 1983 by the World Commission on Environment and Development (also referred to as the Burtland Commission) alerted the world to the fact that by merging the two terms 'sustainable' and 'development', we can refer to the long-term growth and welfare of future generations. Simply, it states that economic development should not come at the expense of harming the current environment where resources are exploited beyond their regenerative capacity [1]. This thinking on sustainability indicators has progressed over the years; and, in 2015, the United Nations (UN) developed a long-term roadmap for achieving sustainable development (SD) by 2030 and beyond. Overall, 193 countries contributed towards the development of 17 sustainable development goals (SDGs) that were applicable to all nations irrespective of their gross domestic product or geographic location. The sustainability development (SD) agenda informed the global agenda by acknowledging issues on combating climate change, protecting biodiversity, providing quality education, reducing social inequalities, promoting economic growth, building sustainable cities and communities, ensuring responsible consumption and production of goods, amongst others. Burford et al. [2] have called for greater contextualization of the SD indicators at a group level rather than referring to them in a generalized manner, since that does not convey local achievements.

The 2022 SD report presented country-level data on each nation's performance levels, and showcased the current country trends towards building a responsible growth strategy [3]. In this article, we have analyzed the SDG achievements pertaining to Asian countries to gain a better understanding of their progress and challenges faced by them. Asia comprises over 48 countries, which have been classified into West Asia, Central Asia, South Asia, East Asia, and Southeast Asia regions (refer to Figure 1). Among these, East

Asia and South Asia have witnessed immense economic and population growth over the past few decades [4]. This has resulted in more resilient societies, although there continues to remain gaps between "the rich and the poor, or between rural and urban, and nor in providing equitable access to vital services such as healthcare and education" ([4], p. 393). As such, many studies have been conducted on the status of sustainable development in these regions, with a focus on the economic, social, health, environmental, innovation and technological fronts [5–7]. Published literature has indicated gaps in terms of access to education, health facilities, financial institutions, natural resources and political freedom amongst others, which leads to an imbalance in meeting the SDGs.

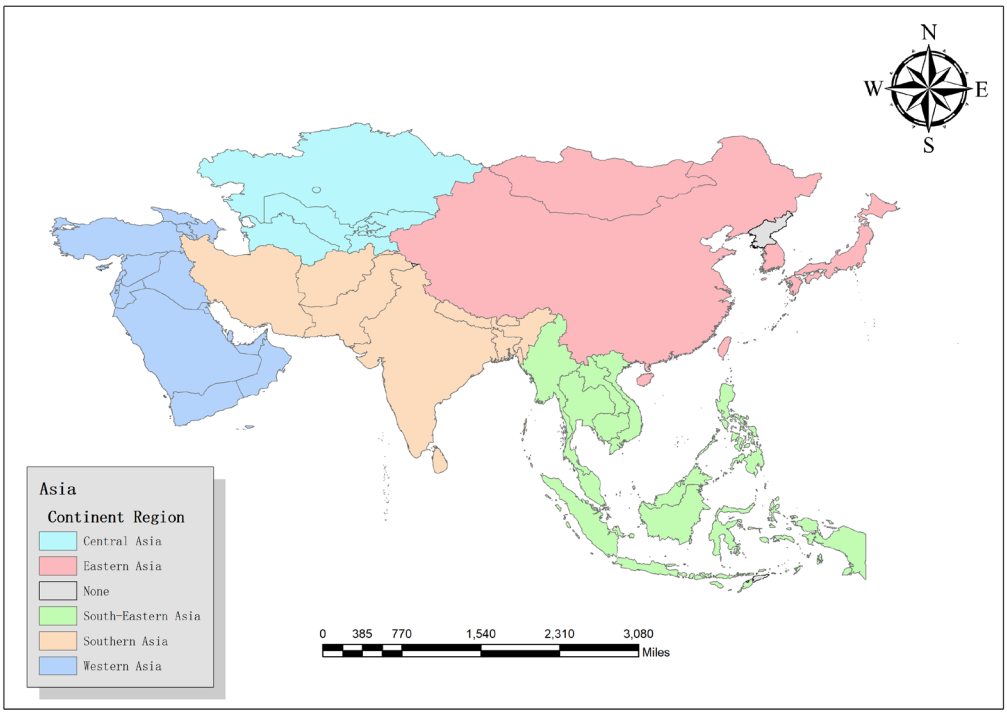

Figure 1. Regional division of Asian countries.

This paper compares the progress and trends in implementing the SDGs from the 2022 UN report from an Asian perspective. We analyzed the geographical commonalities and differences of 45 Asian countries using cluster analysis. The analysis builds upon sixteen SDG progress indicators, five status indicators, and four trend indicators. The clustering of Asian countries using Ward's method is based on the four dimensions, economic, societal, environmental, and institutional, proposed by Moreno and Cueto [8]. The research covers the following two specific objectives:

1. Identify the economic, social, environmental, and institutional strengths and difficulties in achieving sustainable development.
2. Create country clusters that exhibit similar circumstances and trends for achieving sustainable development.

This study provides an up-to-date view on the latest progression of SDGs in the Asian region and leads to a deeper understanding of homogeneous country groups based on their SDG indicators. Compared to the existing literature, this study is more comprehensive and systematic in its coverage of countries, indicators and data, as we explore the latest trends in meeting the SDGs in the context of Asia as a whole. In addition, progress indicators, as well as trend indicators, are projected as dynamic development trends of the SDGs in different Asian country clusters that further reveal present-day differences between different Asian country clusters.

The structure of this paper is as follows. The next section briefly discusses the published research in the sustainable development context. Next, we present the data sources

that were used, data processing methods, and the clustering method that has been applied. Section 4 provides a summary of our results from these analyses, followed by a hypothesis-based discussion with reflective suggestions and recommendations. Finally, we reveal the shortcomings of our experiment, which inform the outlook for conducting future research. The Appendix A provides the scripts used in this study.

2. Literature Review

The UN [9] resolution on SDG is a plan of action for people, the planet and prosperity, although the world today is witnessing military conflicts, climate changes, biodiversity crises, pandemic scenarios and security challenges, all of which have diverted policy attention and priorities away from the SDGs [3]. Considering the complex problems being faced, there is a need for the academic community to intensify the debate with new methodical approaches on sustainable development around the globe, with a greater focus on the developing world context [10]. A recent study has classified countries worldwide from the 2019 SD report to focus on each country's achievements, challenges, needs, strengths, and weaknesses in reaching the SDGs [11]. This study identifies five homogenous clusters worldwide; moreover, it finds that the Central Asian region has same cluster membership with 26 high-income developed countries, while the rest of the Asian regions were clusters with members from lower- or middle-income countries. They conclude that clusters with better socio-economic and politico-cultural structures have a high global SDG index.

Some other studies have focused on the impact of a single SDG [12,13] or a specific type of SDG sector in similar geographical regions (e.g., agriculture-related indicators in Southern African regions [14]). On the other hand, studies of Asian countries comprise articles that mainly focus on examining specific SDGs (e.g., SDG7 [15], SDG2 [16]) or try to explain the interrelationships between SDGs [17,18]. While these studies present us with evidence of national progress for individual indicators and SDG trends in different countries, these are limited to specific economic and environmental regions. Moreover, these studies do not give a comprehensive overview of the complete Asia region, but rather comprise a mix of high and low growth patterns (e.g., high to low fertility patterns that impact the country's social structure, high to low pollution levels based on the country's environmental laws, high to low per capita income depending on the country's economic health, etc.). SD is built on three dimensions—economic, social, and environmental—as these are connected to environmental degradation, social well-being and human workforce [19]. Encouragingly, in line with this objective, some researchers have attempted to investigate sustainability trends in different Asian countries from a more integrated perspective. For example, Yang et al. [6] studied the sustainable development progress of Asia-Pacific countries in terms of the environmental and social impacts of economic growth, highlighting the critical role of the Asia-Pacific region in globalization. Furthermore, Sadiq et al. [20] tested the linkage between the environmental score, social score, governance score, and economic growth, and found positive relationships with SDGs across ASEAN countries. Therefore, this leads us to the formulation of the first hypothesis in this study.

H1: *There is an interrelationship between the economic, social, environmental, and institutional dimensions of the SDGs in Asian countries.*

Each country faces different challenges in implementing the SDGs due to differing national contexts [21]. For instance, many developing countries would have fragmented tracking information, since financial investments are needed to develop a proper monitoring and assessment infrastructure. In particular, less developed countries may be more constrained because of their lack of capital and governance structures [22]. Hence, existing research needs to derive more geographically or qualitatively meaningful results from global indicators. Countries prioritize the SDGs according to their national and then their local-level capacities, such as legal, economic, and environmental governance struc-

tures, before setting up SDG objective practices [23,24]. As such, challenges remain in the internalization of SDGs in a regional and country context.

Cluster analysis has, therefore, been used to classify countries in terms of SD achievements. Jabbari et al. [25] used a statistics-based algorithm to cluster 157 countries based on their level of SDG goal achievement to identify 40 developed countries. In addition, Drastichová and Filzmoser [26] considered the geographical scope and clustered 28 European Union (EU) countries based on four dimensions, economic, social, ecological and institutional, using 12 SDGs from 2012–2016 SDG data. In a subsequent study, Drastichová [27] conducted a hierarchical cluster analysis (HCA) of 29 countries (i.e., EU countries and Norway) to understand the links between nine selected SDG indicators. Another study clustered 27 EU countries based on four SDG indicators using HCA (Ward's method) and K-means clustering at the economic level [28]. The results of all these studies show that most EU countries are moving towards greater sustainability, which could provide lessons and directions for sustainable development in developing countries.

Moreno and Cueto [8] clustered African countries from the 17 SDG indicators of the SD Report 2021 that was released following the COVID-19 pandemic [29]. Their study revealed the uneven implementation of the SDGs across countries, although it identified North African countries to be the best performing countries, while Central African countries were the worst performing countries of the continent. Overall, different regions (i.e., Sub-Saharan Africa, Western Africa, Southern Africa, and Eastern Africa) exhibited excessively disintegrated information across economic, social, environmental and institutional dimensions, making it difficult to provide general conclusions. Ward's clustering was used for grouping the dimensions that showed high degrees of internal homogeneity (within each cluster) and external homogeneity (with other clusters). Accordingly, the second hypothesis was formulated for this study.

H2: *Different geographical regions within the Asian continent show significant variability across different dimensions, which illustrate heterogeneity in SDG progression.*

The Economic and Social Commission for Asia and Pacific report [30] notes much disparity in the demographic and socio-economic characteristics across the various regions; it calls for regional collaboration and partnerships, so that SDG progress can be more equitably achieved. The report adds that many regions may not be on track to achieve the SDGs by 2030 with their limited resources, which have been further burdened with COVID-19 pandemic-induced challenges. Therefore, having clarity on the challenges and hurdles towards achieving SDG, along with a shared regional vision, will enable many nations to move forward on the road map for financial recovery and progress.

3. Research Data Used

The Sustainable Development Report 2022 and the World Bank database have been used in this study [3,31]. Here, the geographical breakdown of the Asian regions and the countries' income levels are taken from the World Bank database, while the SD Report 2022 provided UN data for the defined SDGs. This experiment includes 45 Asian countries, with sixteen SDG indicators for each country, five progress indicators, and four trend indicators.

This study selected indicators provided by Sachs et al. [3], with some necessary adjustments and additions. The following criteria were used to process the data:

1. Indicators that were not comparable across Asia have not been included in this study. For example, SDG 14 or 'Life Below Water' has not been considered, as not all Asian countries have territorial waters (Table 1).
2. The latest data on SDG indicators from Sachs et al. [3] were primarily used. However, if certain data for 2022 were not available, we considered data from the most recent year of the prior SDG report. In addition, countries with significant missing data (i.e., North Korea and Timor-Leste) and those that do not appear in the database (i.e., countries that are not UN members such as Palestine) are not included in this analysis. Figure 1 shows the whole geographical area considered in this research.

3. The raw data are standardized using z-score forward standardization to make SDG indicators comparable across countries and handle any extreme values (e.g., United Arab Emirates score 8.7 for SDG 13). The standardized data are typically distributed with a mean of 0 and a variance of 1. A higher value for each indicator indicates a higher level of sustainable development. The z-score is defined as follows.

$$z = (x - \mu)/\sigma$$

Here, x is the original score, z is the transformed z-score, μ is the mean of scores in the overall sample space, and σ is the standard deviation in the overall sample space.

Table 1. The 16 SDGs considered in this research study.

Goals	Indicator
SDG1	No Poverty
SDG2	No Hunger
SDG3	Good Health and Well-being
SDG4	Quality Education
SDG5	Gender Equality
SDG6	Clean Water and Sanitation
SDG7	Affordable and Clean Energy
SDG8	Decent Work and Economic Growth
SDG9	Industry, Innovation and Infrastructure
SDG10	Reduced Inequalities
SDG11	Sustainable Cities and Communities
SDG12	Responsible Consumption and Production
SDG13	Climate Action
SDG15	Life on Land
SDG16	Peace, Justice and Strong Institutions
SDG17	Partnerships for the Goals

4. Qualitative and Quantitative Experimental Design

The indicator framework proposed by Huan et al. [32] and Moreno and Cueto [8] informed our qualitative design. Huan et al.'s framework classifies 16 SDGs indicators out of 17 SDGs (excluding SDG 14) into the following three dimensions: economic, social, and environmental, while Moreno and Cueto use a four-dimensional classification model (including economic, social, environmental, and institutional dimensions). The dimensions proposed by Moreno and Cueto that considered national institutional change were selected by the author team. Accordingly, the economic dimension considered SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), SDG 10 (Reduced Inequalities), and SDG 12 (Responsible Consumption and Production). The social dimension comprises SDG 1 (No Poverty), SDG 2 (No Hunger), SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), SDG 5 (Gender Equality), SDG 7 (Affordable and Clean Energy) and SDG 11 (Sustainable Cities and Communities). The environmental dimension contains SDG 6 (Clean Water and Sanitation), SDG 13 (Climate Action) and SDG 15 (Life on Land). Finally, the institutional dimension comprises SDG 16 (Peace, Justice, and Strong Institutions) and SDG 17 (Partnerships for the Goals). There are many links between the SDGs. However, each SDG is assigned to a dimension that shows a more direct relationship according to its goals. The final breakdown of the variables is shown in Table 2 below.

Table 2. Dimensionality of the SDGs.

Economic	Social	Environment	Institutional
SDG8	SDG1	SDG6	SDG16
SDG9	SDG2	SDG13	SDG17

Table 2. *Cont.*

Economic	Social	Environment	Institutional
SDG10 SDG12	SDG3 SDG4 SDG5 SDG7 SDG11	SDG15	

Next, the quantitative SDG statistics provided by Sachs et al. [3] informed our study design. The SDG dashboard has highlighted each country's development progress and trends across the 17 goals. The dashboard provided insight into the status and the progress of implementation of the SDGs and revealed the ratings of the 45 Asian countries. The following five progress indicators were provided as ratings: (a) green showing progress = 4 (i.e., target has been met), (b) yellow showing progress = 3 (i.e., some challenges remain), (c) orange showing progress = 2 (i.e., some significant challenges remain), (d) red showing progress = 2 (i.e., many major challenges remain) and (e) grey showing progress = 0 (i.e., there is a lack of sufficient data). Furthermore, in the trend indicators, the green upward arrow indicates the on-track rate of growth required to achieve the SDGs by 2030, with a value of 3. The yellow slanting upward arrow indicates moderate growth, with a value of 2. The orange horizontal arrow indicates stagnated growth, with a value of 1. Finally, the red downward arrow indicates that the trend has worsened, with a value of 0 (Table 3).

Table 3. SDGs' dashboard.

Dashboard		Trend	
Green	Goal achievement (Progress = 4)	↑	On track to maintain achievement (Trend = 3)
Yellow	Challenges remain (Progress = 3)	↗	Moderately increasing (Trend = 2)
Orange	Significant challenges (Progress = 2)	→	Stagnating (Trend = 1)
Red	Major challenges (Progress = 1)	↓	Decreasing (Trend = 0)
Grey	Insufficient data (Progress = 0)		

5. Ward's Method

Cluster analysis is a multi-dimensional statistical method that aims to classify elements in such a way that elements in the same class (group) are more similar to each other than elements located in other classes (groups). The aim is to maximize the homogeneity of elements within classes and the heterogeneity between classes. In other words, cluster analysis is used to understand aspects related to the existence of similar groups. Cluster analysis offers a wide variety of classification methods, and this paper uses the systematic clustering module or Ward's [33] method.

Hierarchical clustering analysis is the most common among the various cluster analysis methods. First, the distances between two n samples (a class containing one sample) are calculated. Then, the two closest classes are merged into a new class. In a bottom-up approach, a series of sequential mergers are formed as we move upward, which can then be shown as a two-dimensional diagram, called a dendrogram. Ward's method is a widely used hierarchical clustering method that is effective when classifying small populations. It is used for finding locally optimal solutions and is based on the idea that if classes are correctly classified, then the sum of squares of deviations should be smaller for similar samples and larger for classes [34]. Each n sample is placed into a class and then reduced by one class at a time. As each class is reduced, the sum of squared differences increases and two classes with the smallest increase in the sum of squared differences are chosen

to merge until all samples are grouped. Ward's error-sum-squared method originated from analysis of variance (ANOVA), which argues that when properly classified, the sum of squared deviations between samples within a class should be relatively small, while the sum of squared deviations between classes is able to achieve the maximum distance between groups and the minimum distance within groups [35]. Moreover, compared to other hierarchical clustering methods, Ward's method is sensitive enough and less distorted when dealing with small volume samples, making it a better method for hierarchical clustering [36]. This study employed Ward's clustering method provided within the SAS analytics software solution (www.sas.com).

6. Results

This section lays out the results from our analysis. Figure 2 shows the clustering results and compares the number of samples in each cluster. The following subsection elaborates on four dimension-based sustainability viewpoints (i.e., economic, social, environmental and institutional). The SDG achievement results are discussed across these four dimension-based sustainability viewpoints.

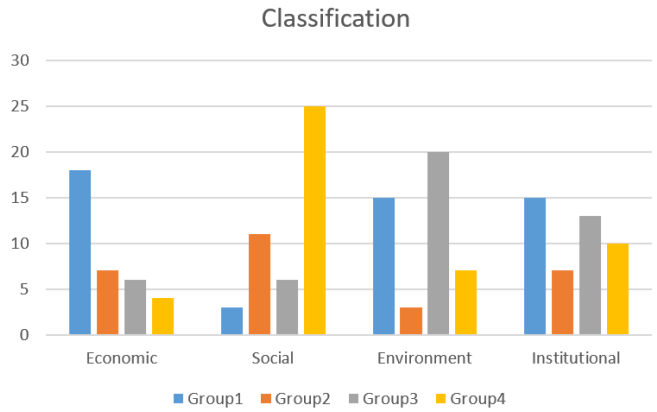

Figure 2. Number of samples in the different clusters.

6.1. Dimension-Based Sustainability

This section frames the results around the four qualitative sustainability dimensions, namely, economic, social, environmental and institutional. We explain each dimension with the use of tree diagrams (dendrograms), country clustering and geographical maps to bring more visual clarity and improve the comprehension of the results obtained from our analysis.

6.1.1. Economic Sustainability

The economic dimension comprises SDG 8, SDG9, SDG10, and SDG 12 (refer Table 2). Figure 3 shows the tree diagram of the economic cluster analysis results.

Our analysis reveals that although all Asian countries face significant or major challenges in the economic dimension of sustainability, these countries are improving moderately, growing at more than 50% of the required growth rate. The results that illustrate forty-five countries are divided into four groups (Table 4). The first group contains seven countries (Bhutan, Lao PDR, Indonesia, Sri Lanka, Vietnam, Georgia and Tajikistan). The countries in this group have good levels of economic development but still need to actively improve their economic environment. The second group consists of 18 developing countries (Afghanistan, Kazakhstan, Kyrgyz Republic, Turkmenistan, etc.), all of which are lower middle-income countries. The third group includes six countries (India, China, Iran, Malaysia, Philippines and Turkey) that still face significant challenges in economic development and are still considered far from those with high economic development. The final group comprises 14 countries, many of which are high-income countries, all of which continue to face significant economic challenges.

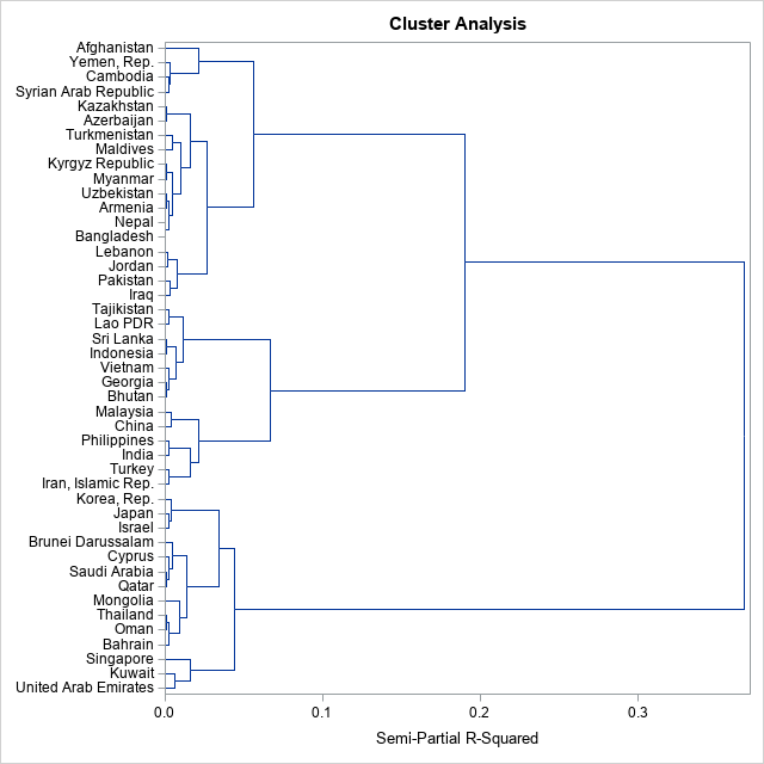

Figure 3. Tree diagram of the economic clusters.

Figure 4 shows that the Southeast Asian countries and the Central Asian countries have a clear advantage in terms of sustainable economic development. Surprisingly, most of the East Asian countries are significantly behind the other regions in sustainable economic development. Given the severe economic impact of the COVID-19 pandemic in the Asia-Pacific region [36], this could have had some impact on their economic growth and recovery plans. Figure 4 shows the country clusters for the economic dimension.

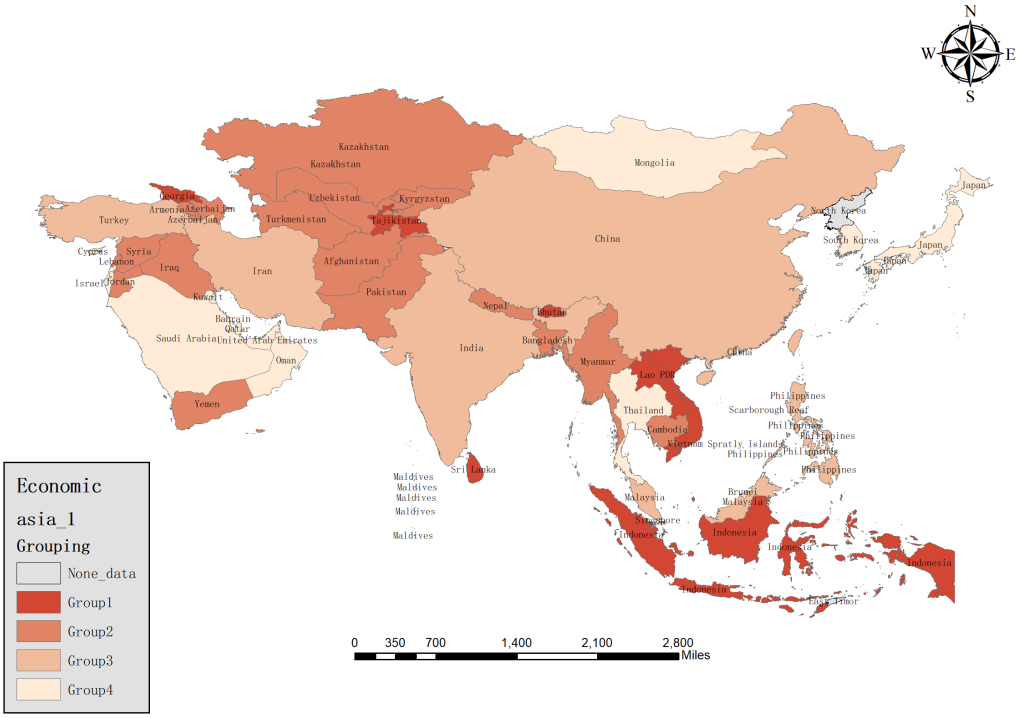

Figure 4. Geographical location results for the economic clusters.

Table 4. Results of the economic clusters.

Group	Country	Progress and Trend	
Group 1	Bhutan, Georgia, Indonesia, Lao PDR, Sri Lanka, Tajikistan, Vietnam	Level = 2.22 Trend = 2.04	Orange ↗
Group 2	Afghanistan, Armenia, Azerbaijan, Bangladesh, Cambodia, Iraq, Jordan, Kazakhstan, Kyrgyz Republic/Kyrgyzstan, Lebanon, Maldives, Myanmar, Nepal, Pakistan, Syrian Arab Republic, Turkmenistan, Uzbekistan, Yemen	Level = 2.08 Trend = 2.31	Orange ↗
Group 3	China, India, Iran, Malaysia, Philippines, Turkey	Level = 1.83 Trend = 2.17	Red ↗
Group 4	Bahrain, Brunei Darussalam, Cyprus, Israel, Japan, Korea, Kuwait, Mongolia, Oman, Qatar, Saudi Arabia, Singapore, Thailand, United Arab Emirates	Level = 1.77 Trend = 2.09	Red ↗

6.1.2. Social Sustainability

The social sustainability cluster contains seven SDGs (namely, SDG 1, SDG 2, SDG 3, SDG 4, SDG 5, SDG 7, and SDG 11, as shown in Table 2). Figure 5 shows the tree diagram of the social cluster analysis results.

According to Table 5 and Figure 6, the Asian countries are clustered into four groups. The first group contains 25 countries, with most East and Central Asian countries and a few Southeast Asian countries. Therefore, it can be observed that this group has the best overall social development indicators of all Asian countries, although the Sustainable Social Development Goals (SDGs) continue to be a key challenge. The trends, however, are not promising, with growth rates below 50% required to achieve SDG growth by 2030. Six countries in Group 2, except for Mongolia, are West Asian countries and these are significantly less socially developed than those in Group 1.

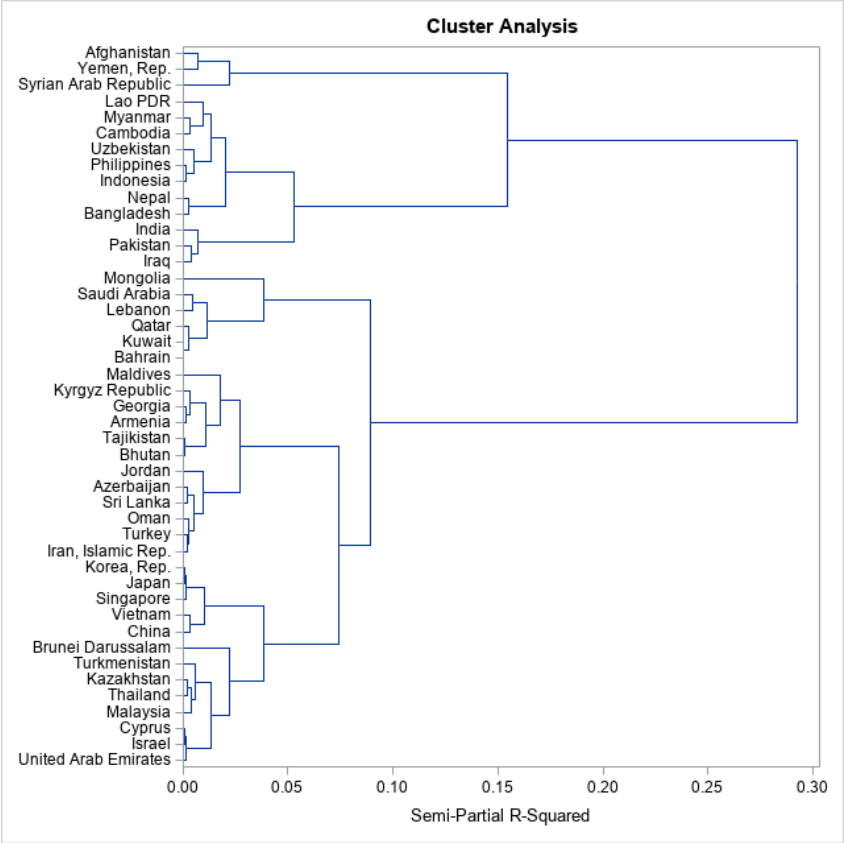

Figure 5. Tree diagram for the social clusters.

Table 5. Results of the social clusters.

Group	Country	Progress and Trend	
Group 1	Armenia, Azerbaijan, Bhutan, Brunei Darussalam, China, Cyprus, Georgia, Iran, Israel, Japan, Jordan, Kazakhstan, Korea, Kyrgyz Republic/Kyrgyzstan, Malaysia, Maldives, Oman, Singapore, Sri Lanka, Tajikistan, Thailand, Turkey, Turkmenistan, United Arab Emirates, Vietnam	Level = 2.21	Orange
		Trend = 1.98	⇄
Group 2	Bahrain, Kuwait, Lebanon, Mongolia, Qatar, Saudi Arabia	Level = 1.64	Red
		Trend = 1.80	⇄
Group 3	Bangladesh, Cambodia, India, Indonesia, Iraq, Lao PDR, Myanmar, Nepal, Pakistan, Philippines, Uzbekistan	Level = 1.60	Red
		Trend = 1.69	⇄
Group 4	Afghanistan, Syrian Arab Republic, Yemen	Level = 0.86	Grey
		Trend = 1.22	⇄

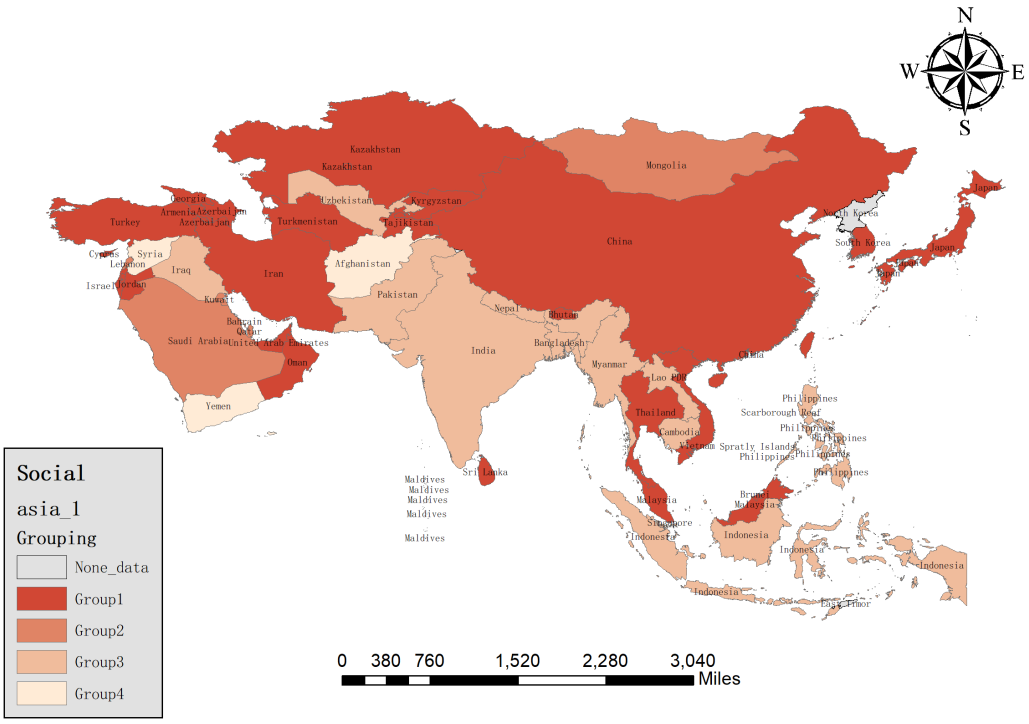

Figure 6. Geographic location results for the social clusters.

Furthermore, social development remains a significant challenge for this group of countries. Group 3 has 11 countries, mainly in South and Southeast Asia, except Iraq and Uzbekistan. Their overall social development and trends are slightly less favorable than Group 2, but the differences are insignificant. The last group consists of only three countries, namely Afghanistan, Yemen, and the Syrian Arab Republic, for which there are insufficient data to determine the level of development. However, it can be assumed that their social development is poor, and they exhibit a stagnant trend. Figure 6 shows the country clusters for the social dimension.

6.1.3. Environmental Sustainability

The environmental sustainability cluster comprises SDG 6, SDG 13, and SDG 15 (refer to Table 2). Figure 7 shows the tree diagram of the cluster analysis results.

The countries in the Asian region are divided into four groups by combining the cluster analysis results in Table 6. Of these, Afghanistan, Sri Lanka, and Yemen were classified as Group 1, and their overall performance is slightly better than Group 2, where development is stagnant. Group 2 includes most Western and Central Asian countries, where environmental sustainability is a significant challenge. Group 3 consists of 20 countries, mainly in South Asia, East Asia, and much of Southeast Asia regions. The overall environmental sustainability indicators are slightly lower than those of Group 2 countries. Group 4 contains seven

countries, and the difference between this group and the last three groups is in the status of the SDGs, where progress in the SDGs is not encouraging, and there is a clear gap with the other countries. The overall performance in this dimension is poor. Figure 8 shows the country clusters for the environment dimension.

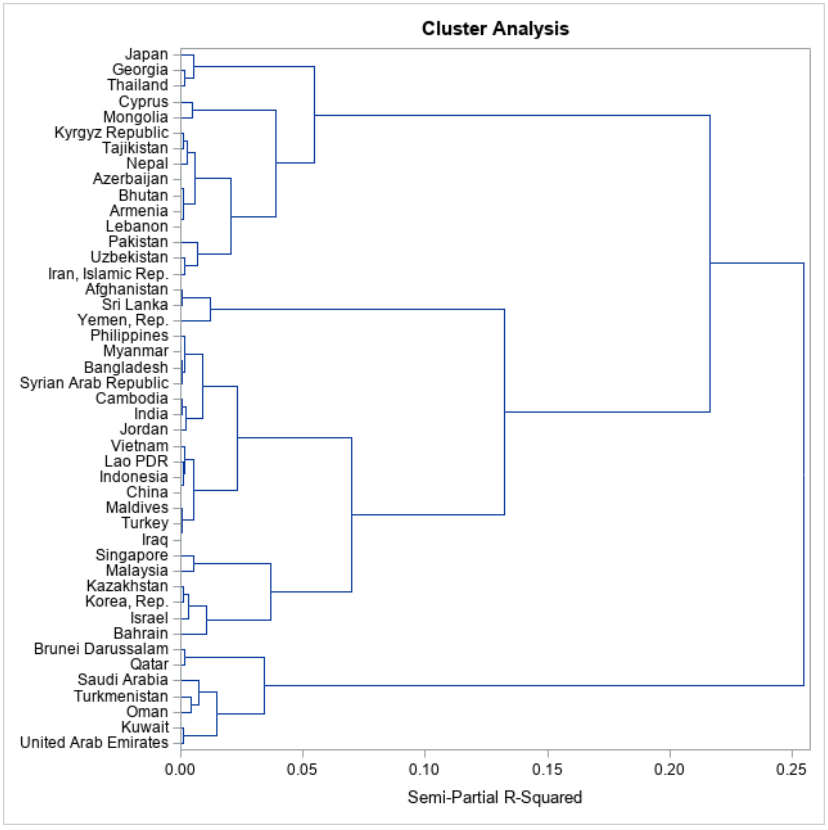

Figure 7. Tree diagram of the environmental clusters.

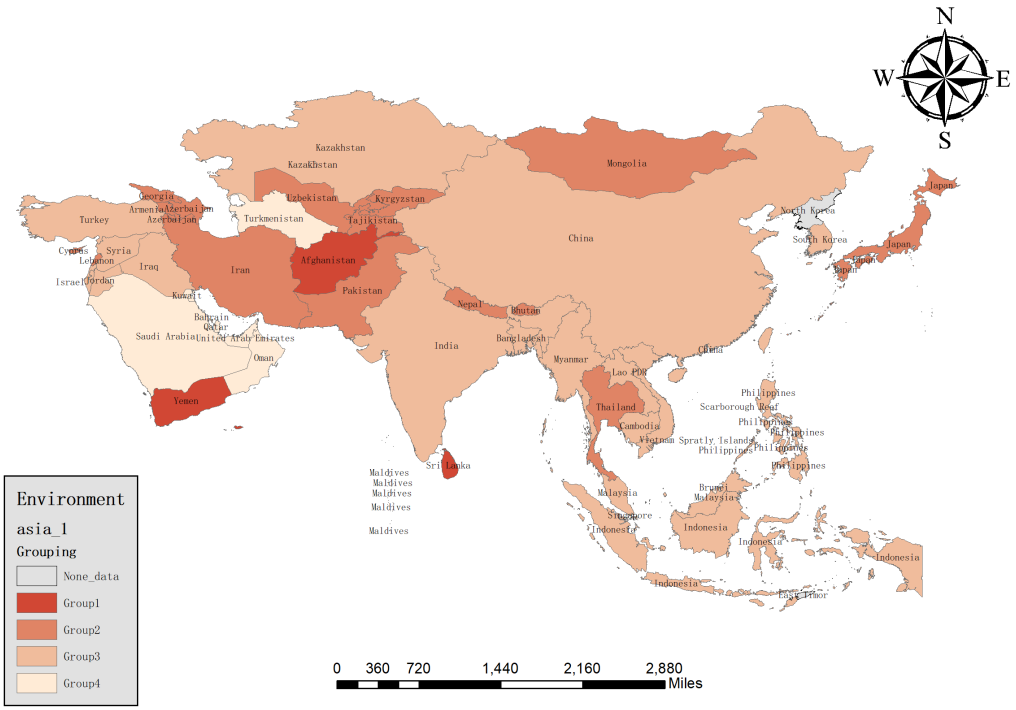

Figure 8. Geographical location of the environmental clusters.

Table 6. Results of the environmental clusters.

Group	Country	Progress and Trend	
Group 1	Afghanistan, Sri Lanka, Yemen	Level = 2	Orange
		Trend = 1.78	⇄
Group 2	Armenia, Azerbaijan, Bhutan, Cyprus, Georgia, Iran, Japan, Kyrgyz Republic/Kyrgyzstan, Lebanon, Mongolia, Nepal, Pakistan, Tajikistan, Thailand, Uzbekistan	Level = 1.82	Red
		Trend = 1.84	⇄
Group 3	Bahrain, Bangladesh, Cambodia, China, India, Indonesia, Iraq, Israel, Jordan, Kazakhstan, Korea, Lao PDR, Malaysia, Maldives, Myanmar, Philippines, Singapore, Syrian Arab Republic, Turkey, Vietnam	Level = 1.77	Red
		Trend = 1.82	⇄
Group 4	Brunei Darussalam, Kuwait, Oman, Qatar, Saudi Arabia, Turkmenistan, United Arab Emirates	Level = 1.14	Red
		Trend = 1.76	⇄

6.1.4. Institutional Sustainability

We placed SDGs 16 and 17 as institutional-based SDGs. Figure 9 shows the tree diagram of the cluster analysis results.

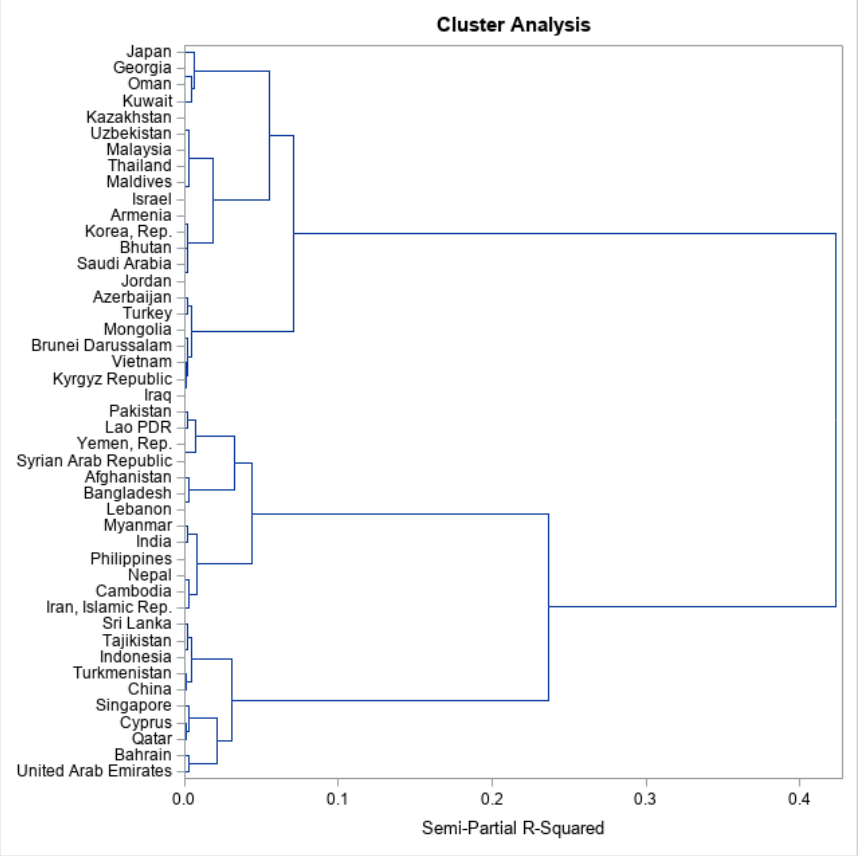

Figure 9. Tree diagram of the institutional clusters.

In this section, 45 Asian countries are again divided into four groups, as shown in Table 7. The 15 countries in Group 1 perform best in all four groups. However, these countries still face significant challenges. Countries in Groups 2, 3 and 4 are all developing in a similar manner, with SDG scores that are increasing but are well below the 2030 target and stagnating, particularly in Group 3.

Figure 10 shows the distribution of countries by group, with the more improved countries mainly in Western and Central Asia and the exceptions being Syria and Yemen, which are in Group 4. In addition, South Korea and Japan in East Asia, and Thailand and Malaysia in Southeast Asia are in the first group. Most of the Eastern and South-eastern Asian countries are in the second and third groups. The countries with the most significant institutional difficulties are those in South Asia.

Table 7. Results of the institutional clusters.

Group	Country	Progress and Trend	
Group 1	Armenia, Bhutan, Georgia, Israel, Japan, Jordan, Kazakhstan, Korea, Kuwait, Malaysia, Maldives, Oman, Saudi Arabia, Thailand, Uzbekistan	Level = 2 Trend = 1.7335	Orange ⇄
Group 2	Azerbaijan, Brunei Darussalam, Iraq, Kyrgyz Republic/Kyrgyzstan, Mongolia, Turkey, Vietnam	Level = 1.643 Trend = 1.488	Red ⇄
Group 3	Bahrain, China, Cyprus, Indonesia, Qatar, Singapore, Sri Lanka, Tajikistan, Turkmenistan, United Arab Emirates	Level = 1.4 Trend = 1.4875	Red ⇄
Group 4	Afghanistan, Bangladesh, Cambodia, India, Iran, Lao PDR, Lebanon, Myanmar, Nepal, Pakistan, Philippines, Syrian Arab Republic, Yemen	Level = 1.346 Trend = 1.308	Red ⇄

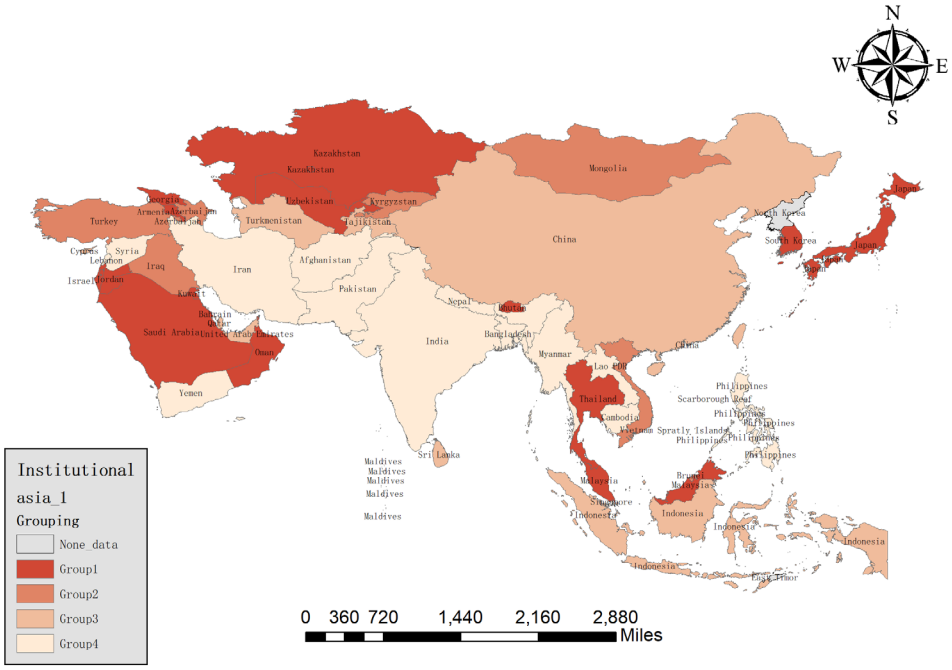

Figure 10. Geographical location results for the institutional clusters.

6.2. Goal-Based Results

This section consolidates the results of the goals in the different dimensions. It provides a more visual representation of the current progress of sustainable development and the specific challenges faced by the different cluster countries.

6.2.1. Economic Goals

Table 8 shows the results of the economic goals. The first two groups of countries showed better progress regarding the SDGs than the other two groups in SDG 10 and SDG 12. The first group of countries showed outstanding progress and trends in SDG 12, while the second group performed well in SDG 10. However, these two countries did not perform as well in SDGs 8 and 9 than in the latter two groups. Combined with Table 4, one can observe that the current progress of sustainable economic development remains a significant challenge for the countries in Groups 3 and 4 and that the poor progress gives rise to this serious challenge. However, it should be noted that these two groups of countries show some SDG trends that are more promising than those in Group 1.

Table 8. Results of the economic goals.

Group	SDG8	SDG9	SDG 10	SDG 12
Group 1	Level = 1.857 Trend = 2.286	Level = 1.571 Trend = 1.857	Level = 2 Trend = 1	Level = 3.429 Trend = 3

Table 8. *Cont.*

Group	SDG8	SDG9	SDG 10	SDG 12
Group 2	Level = 1.222 Trend = 1.667	Leve = 1.556 Trend = 1.667	Level = 2.6 Trend = 3	Level = 3.389 Trend = 2.889
Group 3	Level = 1.333 Trend = 2	Level = 1.833 Trend = 2.5	Level = 1.333 Trend = 1.333	Level = 2.833 Trend = 2.833
Group 4	Level = 2.071 Trend = 2.429	Level = 2.0 Trend = 2.5	Level = 2.143 Trend = 1.6	Level = 1.429 Trend = 1.857

6.2.2. Social Goals

Table 9 shows the results of the social goals. Group 1 demonstrates excellent performance regarding SDG1, indicating that this group of countries experience overall much less poverty issues. In contrast, Group 4 has a Level = 0 for SDG1, and these three countries still face many poverty issues. Group 1 demonstrates the most promising trend for SDG1, which is evidence of the significant progress made towards this goal. The other social SDGs, especially SDG2 and SDG3, have the same level across all subgroups, suggesting that these countries perform relatively similarly regarding the hunger and health goals.

Table 9. Results of the social goals.

Group	SDG1	SDG2	SDG 3	SDG 4	SDG5	SDG7	SD11
Group 1	Level = 3.12 Trend = 2.696	Level = 1.52 Trend = 1.44	Level = 1.72 Trend = 2	Level = 2.88 Trend = 2.47	Level = 1.72 Trend = 1.44	Level = 2.04 Trend = 1.9	Level = 2.44 Trend = 1.8
Group 2	Level = 1.167 Trend = 3	Level = 1.167 Trend = 1.333	Level = 1.667 Trend = 1.83	Level = 2r.5 Trend = 2.4	Level = 1.667 Trend = 1.33	Level = 1.66 Trend = 1.8	Level = 1.66 Trend = 0.8
Group 3	Level = 2 Trend = 1.818	Level = 1.364 Trend = 1.727	Level = 1.091 Trend = 1.81	Level = 2.273 Trend = 2.1	Level = 1.727 Trend = 1.36	Level = 1.45 Trend = 1.7	Level = 1.2 Trend = 1.2
Group 4	Level = 0 Trend = None	Level = 1 Trend = 1	Level = 1 Trend = 1.33	Level = 1 Trend = 2	Level = 1 Trend = 0.67	Level = 1 Trend = 1.3	Level = 1 Trend = 1

6.2.3. Environmental Goals

Table 10 shows the results of the environmental goals. In the environmental sustainability dimension, SDG 13 seems to be the leading cause of the gap. Group 1 countries demonstrate excellent progress and a promising trend regarding SDG 13. This means that Group 1 is the only group of countries in which sustainability is a significant challenge in the environmental sustainability dimension. Overall, Group 2 and Group 3 countries show similar developments in the economic sustainability dimension, with similar progress and trends in all three goals. In Group 4, both the current progress of development and development trends are poor, even though SDG 6 shows excellent development trends.

Table 10. Results of the environmental goals.

Group	SDG6	SDG13	SDG 15
Group 1	Level = 1 Trend = 1.667	Level = 4 Trend = 3	Level = 1 Trend = 0.667
Group 2	Level = 1.867 Trend = 2.4	Level = 2.533 Trend = 1.667	Level = 1.067 Trend = 1.467
Group 3	Level = 1.7 Trend = 2.5	Level = 2.55 Trend = 2.15	Level = 1.05 Trend = 0.8
Group 4	Level = 1 Trend = 2.857	Level = 1.143 Trend = 1.429	Level = 1.286 Trend = 1

6.2.4. Institutional Goals

Table 11 shows the results of the institutional goals. Group 1 and Group 3 display higher levels for SDG16, reflecting the strengths of these two groups of countries in terms

of being less controversial, and having fair and strong institutions. In addition, the three groups of countries other than Group 3 demonstrate excellent progress regarding SDG17.

Table 11. Results of the institutional goals.

Group	SDG16	SDG17
Group1	Level = 2.133 Trend = 1.867	Level = 1.867 Trend = 1.6
Group2	Level = 1.143 Trend = 1.143	Level = 2.143 Trend = 1.833
Group3	Level = 1.7 Trend = 1.6	Level = 1.1 Trend = 1.375
Group4	Level = 1 Trend = 1.154	Level = 1.692 Trend = 1.462

7. Discussion

This section discusses the cluster analysis results around the two hypotheses proposed. The first hypothesis refers to the interconnectedness of development indicators, namely the economic, social, environmental, and institutional indicators, in Asian countries. The results show that the three countries, Syria, Yemen, and Afghanistan, perform very similarly regarding the different SDGs. These three countries are disadvantaged in terms of the socially based SDGs. In contrast, their performance regarding the institutionally based SDGs is poor, possibly indicating a positive correlation between social development and the institutional framework (refer to Appendix B). In addition, East Asia and Central Asian countries, such as Jordan, Kazakhstan, Korea, and Japan, are at the top of both dimensions, which supports this hypothesis. In addition, when comparing the social and economic dimensions, only 2 of the 25 countries in the first tier of the social dimension are in the first stage of the economic dimension. In addition, the three countries at the bottom of the social dimension are in the second stage of the economic dimension, which means that the correlation between the two dimensions does not seem to be high. Similar conclusions can be drawn for the correlation between the social and environmental dimensions. The seven countries with the worst environmental sustainability scores have good social sustainability performance, while the countries with the lowest social sustainability goal scores have excellent environmental sustainability. Finally, the correlation between the economic and environmental sustainability goals was analyzed. Most countries in Central Asia performed similarly in both these dimensions. Of the 15 countries in the second group for the environmental dimension, countries such as Kyrgyzstan and Uzbekistan were found to be in the second group for the economic dimension. Similarly, countries in other regions also performed comparably across both dimensions, showing that economic sustainability is much aligned with environmental sustainability.

The second hypothesis concerns geographical heterogeneity in the progress and trends across the SDGs. Because of the large size of Asia, there is often likely to be geographical variability in development across countries and regions. For example, among the economic-based SDGs, countries in Southeast Asia, such as Indonesia and Vietnam, performed best, while some countries in Central and West Asia, such as Tajikistan and Georgia, performed relatively well; otherwise, countries in East Asia showed average performance. However, it is worth noting that of the 45 Asian countries and regions covered in this study, Japan was the highest ranked Asian country in 2022 and one of only four high-income countries in Asia. The results show that Japan performs well regarding SDG 8 and SDG 9, but is classified in the fourth group for the sustainable economic development indicators. In addition, South Korea, and Cyprus, both developed countries, are also classified in the same group as Japan, as they are both near the sea but have unsustainable economic development. This is evidence of a poor correlation between income levels and economic sustainability. On the other hand, among the socially oriented SDGs, most countries in East Asia, Central Asia, and West Asia, such as China, Iran and Turkey, are relatively more

sustainable. Countries in Southeast Asia performed moderately well. Kumar [4] notes that while many Asian countries have achieved impressive economic growth, they need to consider more constitutional and legal provisions to bring about inclusive growth and social cohesion by implementing a people-centred agenda. The worst performers in terms of social sustainability are Syria, Yemen, and Afghanistan, which are countries that have been affected by war and have been in turmoil in recent years. These unstable factors have led to the inferior performance regarding the social sustainability goals (SDGs 1, 2, 3, 4, 5, 7 and 11) in these countries, to the extent that social data (SDG 1) are challenging to compile.

Among the environment-focused SDGs, Yemen, and Afghanistan are in the top tier of environmental data. These two countries indicate excellent results for SDG 13 data, compared to other Asian countries. This result could be because of their minimal infrastructure and low development of local resources; consequently, their natural environment (SDG 13) is relatively more protected. Some countries in Central Asia also performed well. Central Asian countries are typically arid or semi-arid, as their land policies are hindered by threats of drought and soil salinization, leading to low crop cultivation and marginal land development [37]. In addition, most of the countries in East Asia, Southeast Asia, and West Asia demonstrated average performances in terms of environmental sustainability. It is worth noting that Saudi Arabia, Turkmenistan, and the United Arab Emirates showed a low level of environmental sustainability due to their geographical and ecological context, which is difficult to sustain due to desertification, oil extraction, and soil erosion [38]. The final item is the system-based SDGs. Countries in all regions perform well, such as Japan and South Korea in East Asia and Saudi Arabia in West Asia. However, South Asia is generally the most average performer, which aligns with the findings from a recent study on energy and environmental sustainability [39], while Syria, Yemen, and Afghanistan continue to have poor institutional performance, which is linked to their poor social sustainability. Southeast and East Asian countries are in good positions regarding the 16 SDGs, which is strongly related to their geographic location. However, there are significant limitations to progress and trends in all areas, and they still fall short of the world's leading countries.

8. Conclusions

The focus of this paper was to examine the performance of Asian countries in different dimensions of SDGs and test the validity of two stated hypotheses. The authors argue that sustainable development in Asia is not only related to geographical location, with seafaring countries achieving more progress regarding the SDGs than landlocked countries. East and Southeast Asian countries also have the highest overall sustainable development performance in Asia. Moreover, there are correlations between the different dimensions of development indicators. For example, there is a positive correlation between the society and institutions and between the environment and economy, but the correlation between the society and environment and between the society and economy is not high.

In addition, this research also found that high-income developed countries do not perform as well as low- and middle-income countries in the economic dimension of sustainability. This result implies that there may be some evidence of a negative correlation between economic sophistication and sustainability, but this has not been confirmed. It is one of the research limitations of this paper. In addition, this study only focuses on countries within the Asian region and not across the world. There are still three Asian countries that have not been documented and explored, so only rough conclusions can be drawn.

Furthermore, this study only discusses 16 SDG indicators and does not explore 120 detailed indicators. Therefore, we plan to expand our study in the future to examine SDGs in various countries and regions around the world to draw out more insightful findings. Alternatively, detailed indicators can be explored to summarize each country's strengths and weaknesses and suggest more options for the direction of development in each country.

In summary, the research in this paper has positive implications for understanding sustainable development in Asian countries. We have proposed a cluster analysis method

that fills the gap in the study of Asian countries in terms of the classification of sustainable development goals and points out the increases in the level of sustainable development and the noticeable gaps in the context of Asian countries. It provides a wider picture of the current progression levels of the social, economic, environmental and institutional goals across 45 Asian countries. This study's results will support policymakers in establishing appropriate country-specific decisions as they consider future strategies. A closer look into individual countries within each group can assist them in supporting each other for building existing synergies and long-term resilience to meet the 2030 sustainable development targets.

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Appendix A

The appendix provides the SAS codes used in this analysis.

```
proc contents data=test varnum;
title 'Analysis Content';
run;
proc print data=test;
title 'Analysis Print';
run;
/*Clustering analysis - Country Economic*/
ods graphics on;
PROC CLUSTER DATA=test standard method=ward CCC pseudo out=test1;
var 'Goal 8 Score 'n 'Goal 9 Score'n 'Goal 10 Score'n 'Goal 12 Score'n;
id Country;
title 'Cluster Analysis - ward Country Economic';
run;
ods graphics off;
/*Clustering analysis - Country Social*/
ods graphics on;
PROC CLUSTER DATA=test standard method= ward CCC pseudo out=test1;
var 'Goal 1 Score'n 'Goal 2 Score'n 'Goal 3 Score'n 'Goal 4 Score'n 'Goal 5 Score'n 'Goal 7
Score'n 'Goal 11 Score'n;
id Country;
title 'Cluster Analysis - ward Country Social';
run;
ods graphics off;
/*Clustering analysis - Country Environment*/
ods graphics on;
PROC CLUSTER DATA=test standard method= ward CCC pseudo out=test1;
var 'Goal 6 Score'n 'Goal 13 Score'n 'Goal 15 Score'n;
id Country;
title 'Cluster Analysis - ward Country Environment';
run;
```

```
ods graphics off;
/*Clustering analysis - Institutional'*/
ods graphics on;
PROC CLUSTER DATA=test method= ward PLOTS CCC pseudo out=test1;
var 'Goal 16 Score'n 'Goal 17 Score'n;
id Country;
title 'Cluster Analysis- ward Institutional';
run;
ods graphics off
```

Appendix B

The correlation and *p*-values of the SDGs are provided in this section.

Correlation Matrix of the 16 SDGs Considered in This Study

		Economic				**Environment**			**Institutional**					**Social**			
		SDG8	SDG9	SDG10	SDG12	SDG6	SDG13	SDG15	SDG16	SDG17	SDG1	SDG2	SDG3	SDG4	SDG5	SDG7	SDG11
SDG8	r	1	0.538 **	−0.111	−0.391 **	0.417 **	−0.303 *	0.008	0.491 **	0.068	0.181	0.467 **	0.590 **	0.667 **	0.612 **	0.304 *	0.442 **
	p-val.		0	0.469	0.008	0.004	0.043	0.961	0.001	0.655	0.235	0.001	0	0	0	0.042	0.002
SDG9	r	0.538 **	1	−0.143	−0.743 **	0.318 *	−0.560 **	−0.134	0.623 **	0.114	0.445 **	0.570 **	0.817 **	0.600 **	0.407 **	0.219	0.365 *
	p-val.	0		0.35	0	0.034	0	0.382	0	0.454	0.002	0	0	0	0.006	0.148	0.014
SDG10	r	−0.111	−0.143	1	−0.145	−0.009	−0.179	0.323 *	0.146	0.033	0.149	−0.12	0.017	−0.072	−0.011	−0.086	−0.137
	p-val.	0.469	0.35		0.341	0.952	0.239	0.03	0.337	0.83	0.328	0.432	0.912	0.637	0.944	0.573	0.371
SDG12	r	−0.391 **	−0.743 **	−0.145	1	−0.17	0.787 **	0.07	−0.604 **	−0.089	−0.480 **	−0.293	−0.730 **	−0.500 **	−0.324 *	−0.045	−0.194
	p-val.	0.008	0	0.341		0.263	0	0.646	0	0.561	0.001	0.051	0	0	0.03	0.769	0.202
SDG6	r	0.417 **	0.318 *	−0.009	−0.17	1	0.133	−0.064	0.364 *	0.261	0.193	0.27	0.375 *	0.384 **	0.535 **	0.412 **	0.428 **
	p-val.	0.004	0.034	0.952	0.263		0.382	0.678	0.014	0.083	0.204	0.073	0.011	0.009	0	0.005	0.003
SDG13	r	−0.303 *	−0.560 **	−0.179	0.787 **	0.133	1	−0.072	−0.426 **	−0.001	−0.236	−0.253	−0.555 **	−0.408 **	−0.259	0.087	−0.043
	p-val.	0.043	0	0.239	0	0.382		0.639	0.004	0.993	0.118	0.093	0	0.005	0.085	0.57	0.781
SDG15	r	0.008	−0.134	0.323 *	0.07	−0.064	−0.072	1	0.125	0.253	−0.011	−0.132	0.009	0.141	0.067	0.013	−0.021
	p-val.	0.961	0.382	0.03	0.646	0.678	0.639		0.413	0.094	0.941	0.387	0.955	0.355	0.664	0.933	0.893
SDG16	r	0.491 **	0.623 **	0.146	−0.604 **	0.364 *	−0.426 **	0.125	1	0.233	0.501 **	0.507 **	0.750 **	0.530 **	0.444 **	0.521 **	0.481 **
	p-val.	0.001	0	0.337	0	0.014	0.004	0.413		0.124	0	0	0	0	0.002	0	0.001
SDG17	r	0.068	0.114	0.033	−0.089	0.261	−0.001	0.253	0.233	1	0.029	−0.049	0.152	0.059	−0.032	0.155	0.313 *
	p-val.	0.655	0.454	0.83	0.561	0.083	0.993	0.094	0.124		0.851	0.748	0.32	0.701	0.835	0.308	0.036
SDG1	r	0.181	0.445 **	0.149	−0.480 **	0.193	−0.236	−0.011	0.501 **	0.029	1	0.143	0.580 **	0.297 *	0.109	0.093	0.239
	p-val.	0.235	0.002	0.328	0.001	0.204	0.118	0.941	0	0.851		0.349	0	0.047	0.478	0.544	0.114
SDG2	r	0.467 **	0.570 **	−0.12	−0.293	0.27	−0.253	−0.132	0.507 **	−0.049	0.143	1	0.487 **	0.502 **	0.592 **	0.288	0.303 *
	p-val.	0.001	0	0.432	0.051	0.073	0.093	0.387	0	0.748	0.349		0.001	0	0	0.055	0.043
SDG3	r	0.590 **	0.817 **	0.017	−0.730 **	0.375 *	−0.555 **	0.009	0.750 **	0.152	0.580 **	0.487 **	1	0.705 **	0.461 **	0.431 **	0.546 **
	p-val.	0	0	0.912	0	0.011	0	0.955	0	0.32	0	0.001		0	0.001	0.003	0
SDG4	r	0.667 **	0.600 **	−0.072	−0.500 **	0.384 **	−0.408 **	0.141	0.530 **	0.059	0.297 *	0.502 **	0.705 **	1	0.655 **	0.239	0.474 **
	p-val.	0	0	0.637	0	0.009	0.005	0.355	0	0.701	0.047	0	0		0	0.114	0.001
SDG5	r	0.612 **	0.407 **	−0.011	−0.324 *	0.535 **	−0.259	0.067	0.444 **	−0.032	0.109	0.592 **	0.461 **	0.655 **	1	0.279	0.515 **
	p-val.	0	0.006	0.944	0.03	0	0.085	0.664	0.002	0.835	0.478	0	0.001	0		0.064	0

Correlation Matrix of the 16 SDGs Considered in This Study																
		Economic				**Environment**			**Institutional**				**Social**			
		SDG8	SDG9	SDG10	SDG12	SDG6	SDG13	SDG15	SDG16	SDG17	SDG1	SDG2	SDG3	SDG4	SDG5	SDG7	SDG11
SDG7	r	0.304 *	0.219	−0.086	−0.045	0.412 **	0.087	0.013	0.521 **	0.155	0.093	0.288	0.431 **	0.239	0.279	1	0.555 **
	p-val.	0.042	0.148	0.573	0.769	0.005	0.57	0.933	0	0.308	0.544	0.055	0.003	0.114	0.064		0
SDG11	r	0.442 **	0.365 *	−0.137	−0.194	0.428 **	−0.043	−0.021	0.481 **	0.313 *	0.239	0.303 *	0.546 **	0.474 **	0.515 **	0.555 **	1
	p-val.	0.002	0.014	0.371	0.202	0.003	0.781	0.893	0.001	0.036	0.114	0.043	0	0.001	0	0	

* *p*-val. <= 0.05, ** *p*-val. <= 0.001.

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