

Classifying Islamic Countries by Governance Indicators through PCA and Model-Based Clustering (MCLUST)

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Send Article Date: 08 /08/2025

Date of acceptance of the article: 11/11/2025

Abstract:

This study aims to classify 57 Islamic countries based on their governance performance for the year 2023. Relying on six key governance indicators from the World Bank namely Control of Corruption, Government Effectiveness, Political Stability and Absence of Violence/Terrorism, Regulatory Quality, Rule of Law, and Voice and Accountability, the study adopts a two-stage analytical approach. First, Principal Component Analysis (PCA) is used to reduce the dimensionality of the data while retaining most of its variance. Then, Model-Based Clustering is performed using the MCLUST algorithm in the R environment to uncover latent governance-based groupings.

The results identify two distinct clusters: the first includes 48 countries characterized by heterogeneous and generally lower governance scores, while the second comprises 9 countries with relatively high and consistent institutional performance. These findings highlight the significant governance disparities across the Islamic world and underscore the urgent need for institutional reforms focused on transparency, regulatory quality, and administrative effectiveness.

key words: Governance; Governance Indicators; Islamic Countries; Model-Based Clustering; PCA; MCLUST.

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1. Introduction:

In recent decades, governance has become a central concern for policymakers, researchers, and international organizations, due to its fundamental role in promoting sustainable economic, social, and political development. The effectiveness of public institutions, adherence to the rule of law, regulatory quality, and the control of corruption are all core pillars of sound governance that foster trust between governments and citizens, attract investment, and enhance institutional resilience.

In the context of the complex and diverse political, economic, and institutional trajectories experienced by Islamic countries, assessing and improving governance quality has become increasingly urgent. The Islamic world encompasses countries with wide-ranging institutional frameworks, socio-economic conditions, and reform paths. Therefore, evaluating governance through internationally recognized indicators has become a vital step toward identifying weaknesses, benchmarking progress, and guiding policy interventions.

To this end, the use of advanced statistical methods capable of revealing hidden patterns and grouping countries based on governance similarities has become indispensable. Among such methods, the combination of Principal Component Analysis (PCA) and Model-Based Clustering (MCLUST) offers a powerful approach to reduce data complexity and classify countries objectively. This study adopts this modern methodology to explore the governance landscape of 57 Islamic countries and identify distinct governance profiles based on empirical evidence.

1.1. Research Problem:

Despite increasing global attention to the importance of governance, many Islamic countries continue to face institutional challenges that hinder their development efforts. These challenges vary in intensity and form across countries, making it difficult to adopt a one-size-fits-all approach to governance reform. Understanding the structure and diversity of governance performance within the Islamic world therefore requires a data-driven classification that moves beyond anecdotal assessments.

In this context, the central problem addressed by this study is the lack of a systematic and empirical classification of Islamic countries based on internationally recognized governance indicators. This raises the following research question :

To what extent do governance patterns vary among Islamic countries, and how can these countries be meaningfully classified using quantitative methods such as PCA and model-based clustering (MCLUST)?

1.2. Research Objectives:

This study aims to:

- Analyze the governance performance of Islamic countries using the six World Bank governance indicators;
- Apply Principal Component Analysis (PCA) to reduce dimensionality and reveal latent governance structures;
- Use the MCLUST model-based clustering approach to classify countries into meaningful groups based on governance quality;
- Highlight the key institutional characteristics that distinguish the identified clusters.

1.3. Research Significance:

The significance of this study lies in its contribution to the empirical understanding of governance disparities within the Islamic world. By using modern and robust statistical methods, the study provides evidence-based insights into the institutional landscape of Islamic countries. These insights are essential for policymakers, development agencies, and international organizations working to design governance reforms tailored to each country's specific challenges and institutional realities.

2. The Conceptual Framework of Governance:

This section presents the theoretical foundations of governance by first reviewing its definitions, followed by an examination of its core dimensions and associated indicators.

2.1. Definition of Governance:

Governance has been approached from multiple perspectives, reflecting its multidimensional nature. One widely cited definition is that of the United Nations, which considers governance as the set of processes through which decisions are formulated and executed.¹

In a complementary view, the International Monetary Fund (IMF) conceptualizes governance as a framework aimed at enhancing transparency in public sector operations. It emphasizes the effective management of public resources and the creation of a conducive environment for private sector development.²

2.2. Dimensions of Governance:

Governance encompasses several fundamental dimensions through which institutional performance and state-society relations can be analyzed:³

- **Political Dimension:** This aspect pertains to the structure of political authority and the legitimacy of its representation. It reflects the nature of interaction between governing institutions and the governed population. When democratic principles are genuinely upheld, this relationship fosters trust, cooperation, and a collective commitment to the public good.
- **Economic and Social Dimension:** This dimension addresses the level of economic performance aimed at fostering development, promoting transparency, and combating corruption. It also contributes to minimizing investment risks by ensuring the regular and transparent dissemination of economic data. On the social side, the focus is on achieving distributive justice, improving living conditions, and eliminating poverty.
- **Administrative Dimension:** This component relates to the efficient and equitable management of public resources both financial and human through mechanisms such as decentralization. The effectiveness and sustainability of public administration depend largely on the capacity of the bureaucratic system, the strength of legal frameworks, and the integrity of governance practices.

¹ UNESCAP, What is Governance? Retrieved 06 01, 2025, from <http://www.unescap.org/sites/default/files/good-governance.pdf>, 2009.

² Tawfiq, Rawia, Good Governance and Development in Africa: An Analytical Study of the NEPAD Initiative. Institute of African Research and Studies, (Vol. 1), 2005, p. 25.

³ Al-Louzi, Mousa, Administrative Development: Concepts, Foundations, and Applications. Amman: Dar Wael, 2000, p.71.

2.3. Indicators of Good Governance:

The Worldwide Governance Indicators (WGI) developed by the World Bank are widely regarded as one of the most authoritative and comprehensive frameworks for evaluating governance performance across countries. These indicators encompass political, economic, and institutional dimensions and are composed of six key measures that collectively provide a holistic assessment of governance quality.⁴

2.3.1. Voice and Accountability:

This indicator reflects the extent to which citizens are empowered to participate in the political process, particularly through free and fair elections. It also captures fundamental civil liberties, such as freedom of expression, association, and press independence, which are essential for democratic governance and citizen engagement.

2.3.2. Political Stability and Absence of Violence/Terrorism:

This dimension evaluates the risks of political unrest and the occurrence of violence driven by political motives. It accounts for factors such as internal conflicts, terrorism, ethnic tensions, coups, and the overall fragility of political systems, offering insight into a country's institutional resilience and security environment.

2.3.3. Government Effectiveness:

This indicator measures the performance of the public sector, focusing on the quality and reliability of public services, the professionalism and independence of the civil service, and the coherence and credibility of policy formulation and implementation. It provides an overall assessment of bureaucratic efficiency and administrative capacity.

2.3.4. Regulatory Quality:

This component gauges the government's ability to design and enforce sound regulatory policies that facilitate private sector development and economic competitiveness. It highlights the predictability, consistency, and efficiency of the regulatory environment in which businesses and citizens operate.

2.3.5. Rule of Law:

This measure captures the degree of trust in legal institutions and the effectiveness of law enforcement mechanisms. It reflects the extent to which laws are applied impartially, contracts are enforced, property rights are protected, and individuals whether in power or not are held accountable under the law. It also includes perceptions of crime prevalence and judicial reliability.

2.3.6. Control of Corruption:

This indicator examines the extent to which the exercise of public authority is free from corruption. It includes perceptions of both petty and grand corruption, as well as the degree to which political and economic elites may influence state institutions for personal gain. It serves as a proxy for transparency, integrity, and accountability in public administration.

3. Application of PCA and Model-Based Clustering (MCLUST) to Classify Islamic Countries by Governance Performance:

3.1. Overview of the Features and Tools of the MCLUST Method:

MCLUST is a leading approach for unsupervised classification based on Gaussian mixture models. It offers a comprehensive framework that combines model-based hierarchical clustering,

⁴ Kaufmann, Daniel, The worldwide governance indicators: Methodology and analytical issues. World Bank policy research working paper, (pp. 30-54), 2010, p. 37.

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the Expectation-Maximization (EM) algorithm for parameter estimation, and several tools for optimal model and cluster selection. The method is highly flexible, allowing users to specify different covariance structures and apply cross-component constraints. Additionally, it provides tools for simulating data, performing detailed estimation steps, and visualizing results related to clustering, classification, and density estimation. Recent versions of the method include enhanced features such as dimension reduction for visualization, improved initialization options, and extended criteria for model selection.⁵

The MCLUST currently offers a range of advanced features, including:⁶

- Gaussian mixture modeling via the Expectation-Maximization (EM) algorithm, with fourteen different covariance structures and cross-component constraints (structured GMMs);
- Data simulation from all available model specifications;
- Model-based clustering that integrates structured GMM fitting with model selection using BIC and other criteria;
- Density estimation based on Gaussian mixtures;
- Tools for merging mixture components to improve clustering results;
- Discriminant analysis (supervised classification) using structured GMMs (e.g., EDDA, MclustDA), along with semi-supervised classification methods;
- Dimension reduction techniques tailored for clustering and classification;
- Visualization tools, including uncertainty plots, random projections, contour and perspective graphs, classification diagrams, and 1D/2D density plots.

3.2. Study Presentation:

3.2.1. Methodology:

The empirical methodology adopted in this study combines Principal Component Analysis (PCA) with Model-Based Clustering using the MCLUST package in R.

This approach enables the unsupervised classification of Islamic countries based on key governance indicators. PCA is first applied to reduce dimensionality while preserving most of the variance, followed by the MCLUST algorithm to detect latent clusters in the reduced space.

3.2.2. Study Sample and Period:

The study focuses on the year 2023 and covers the entire group of 57 member states of the Organisation of Islamic Cooperation (OIC). These countries represent the Islamic world across different regions, including the Middle East, North Africa, Sub-Saharan Africa, Central and South Asia, and Southeast Asia.

3.2.3. Data Sources :

Governance data were sourced from the Worldwide Governance Indicators (WGI) database, published by the World Bank Group.⁷

This database is among the most widely used international references for assessing governance quality, covering over 200 countries and territories from 1996 to 2023.

⁵ Luca Scrucca, Chris Fraley, T. Brendan Murphy, and Adrian E. Raftery, *Model-Based Clustering, Classification, and Density Estimation Using mclust in R*, 1st Edition, Chapman and Hall, CRC, 2023, pp: 2-3.

⁶ Ibid., p. 4.

⁷ World Bank Group, *Worldwide Governance Indicators*. Retrieved 06-05-2025, from <https://databank.worldbank.org/source/worldwide-governance-indicators#>, 2025.

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3.2.4. Study Variables:

The classification is based on the six core governance dimensions provided by the WGI database:

- Control of Corruption (CC);
- Government Effectiveness (GE);
- Political Stability and Absence of Violence/Terrorism (PS);
- Regulatory Quality (RQ);
- Rule of Law (RL);
- Voice and Accountability (VA).

3.3. Preliminary Statistical Assessment of the Data:

Before proceeding with dimensionality reduction and clustering techniques, a preliminary statistical assessment was conducted to evaluate the dispersion of the six governance indicators. The standard deviation of each variable was calculated, and the results indicated sufficient variability in the data, as shown below:

Table (01): Standard Deviation of the Governance Indicators (2023)

Indicator	Standard Deviation
Control of Corruption (CC)	0.68
Government Effectiveness (GE)	0.86
Political Stability (PS)	0.99
Regulatory Quality (RQ)	0.78
Rule of Law (RL)	0.75
Voice and Accountability (VA)	0.57

Source: Prepared by the author based on the R software

This confirms that all indicators contribute meaningfully to the classification process, and none of them is constant or exhibits negligible variation that would require exclusion.

3.4. Principal Component Analysis (PCA):

In order to reduce the dimensionality of the data and facilitate a more interpretable classification process, a Principal Component Analysis (PCA) was conducted on the standardized values of the six governance indicators. The objective of PCA in this context is to transform the original correlated variables into a smaller set of uncorrelated components (principal components) that retain most of the variance present in the original dataset.

Table (02): Results of Principal Component Analysis on Governance Indicators (2023)

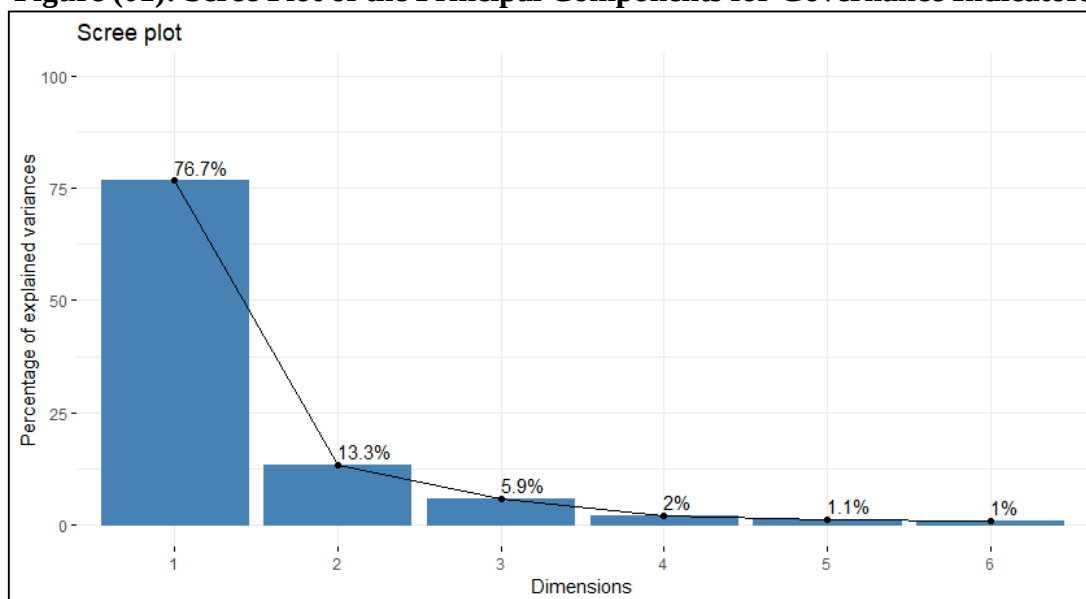
Component	Standard Deviation	Proportion of Variance	Cumulative Variance
PC1	2.1447	0.7666	0.7666
PC2	0.8928	0.1329	0.8994
PC3	0.5971	0.0594	0.9589
PC4	0.3490	0.0203	0.9792
PC5	0.2596	0.0112	0.9904
PC6	0.2401	0.0096	1.0000

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Source: Prepared by the author based on the R software

The results of the PCA are summarized in Table (02), which presents three key metrics for each principal component: the standard deviation, the proportion of variance explained, and the cumulative proportion of variance. As shown in the table, the first principal component (PC1) explains approximately 76.66% of the total variance in the dataset, while the second principal component (PC2) explains an additional 13.29%. Together, these two components account for about 89.94% of the total variance.

Figure (01): Scree Plot of the Principal Components for Governance Indicators



Source: Prepared by the author based on the R software

To visualize the importance of each component, a Scree Plot was generated (Figure 1). This graph displays the proportion of variance explained by each component. A clear "elbow" is observed at the second component, confirming that retaining the first two components is a justified and efficient dimensionality reduction strategy. The remaining components (PC3 to PC6) each account for less than 6% of the total variance individually, and their cumulative contribution beyond the second component is marginal.

Accordingly, only the first two principal components (PC1 and PC2) were retained for further analysis and used as input for the model-based clustering method (MCLUST). This dimensionality reduction not only enhances computational efficiency but also enables intuitive visual interpretation of the clusters in a two-dimensional space.

3.5. Application of the MCLUST Clustering Method on Principal Components:

After reducing the dimensionality of the six governance indicators using Principal Component Analysis (PCA), the first two principal components, which together explain approximately 89.9% of the total variance, were retained for further analysis. These components serve as a condensed representation of the original governance dataset.

The MCLUST algorithm was then applied to the dataset projected in the two-dimensional principal component space. This method, which relies on Gaussian mixture models,

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automatically determines the optimal number of clusters based on the Bayesian Information Criterion (BIC).

The optimal model selected by BIC corresponds to the VEV structure with two clusters.

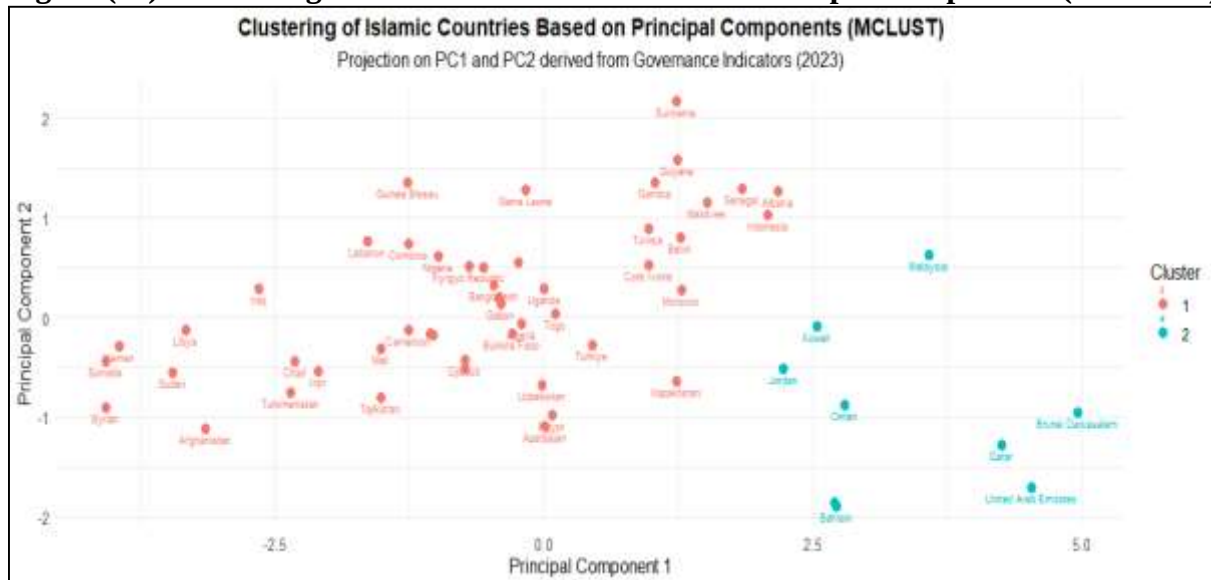
Table (03): Classification of Islamic Countries Using MCLUST Based on Governance Indicators (2023)

Country	Group	Uncertainty	Country	Group	Uncertainty
Afghanistan	1	0.000	Malaysia	2	0.431
Albania	1	0.019	Maldives	1	0.006
Algeria	1	0.001	Mali	1	0.000
Azerbaijan	1	0.028	Mauritania	1	0.000
Bahrain	2	0.000	Morocco	1	0.021
Bangladesh	1	0.000	Mozambique	1	0.000
Benin	1	0.007	Niger	1	0.000
Brunei Darussalam	2	0.000	Nigeria	1	0.000
Burkina Faso	1	0.001	Oman	2	0.010
Cameroon	1	0.000	Pakistan	1	0.000
Chad	1	0.000	Qatar	2	0.000
Comoros	1	0.000	Saudi Arabia	2	0.000
Cote Ivoire	1	0.005	Senegal	1	0.010
Djibouti	1	0.000	Sierra Leone	1	0.000
Egypt	1	0.023	Somalia	1	0.000
Gabon	1	0.000	Sudan	1	0.000
Gambia	1	0.002	Suriname	1	0.002
Guinea	1	0.000	Syrian	1	0.000
Guinea Bissau	1	0.000	Tajikistan	1	0.000
Guyana	1	0.002	Togo	1	0.001
Indonesia	1	0.025	Tunisia	1	0.003
Iran	1	0.000	Turkiye	1	0.009
Iraq	1	0.000	Turkmenistan	1	0.000
Jordan	2	0.196	Uganda	1	0.001
Kazakhstan	1	0.260	United Arab Emirates	2	0.000
Kuwait	2	0.363	Uzbekistan	1	0.006
Kyrgyz Republic	1	0.000	Palestine	1	0.000
Lebanon	1	0.000	Yemen	1	0.000
Libya	1	0.000			

Source: Prepared by the author based on the R software

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Figure (02): Clustering of Islamic Countries Based on Principal Components (MCLUST)



Source: Prepared by the author based on the R software

The scatter plot derived from the PCA-MCLUST process provides a clear visual representation of the spatial distribution of Islamic countries in the reduced two-dimensional governance space. Each point on the graph corresponds to a country, whose coordinates are determined by its scores on the first two principal components. These components summarize the combined influence of the six original governance indicators, and their axes can be interpreted as latent dimensions of institutional quality.

Countries are colored according to the cluster assigned by the MCLUST algorithm, enabling immediate identification of structural similarities in governance profiles. Labels for each point indicate the country names, facilitating a country-level interpretation. The spatial grouping reveals natural divisions between nations, while proximity between points within the same cluster suggests similar governance dynamics. The compactness of Cluster 2, for example, contrasts with the wider spread of Cluster 1, hinting at higher internal coherence in the governance models of the former.

The results of the classification presented in both the table and the figure highlight the emergence of two clearly distinguishable groups among the 57 Islamic countries :

- **Cluster 1 – (48 countries):** This cluster contains the vast majority of the sample. These countries exhibit a wide range of governance outcomes, but on average, they share lower or moderate performance across the six governance indicators. Their dispersion in the PCA space reflects institutional heterogeneity, suggesting varying levels of administrative capacity, political stability, and regulatory quality. The diversity in governance profiles may reflect different historical legacies, levels of economic development, and reform trajectories
- **Cluster 2 – (9 countries):** This smaller, more homogeneous cluster includes: Bahrain, Brunei Darussalam, Jordan, Kuwait, Malaysia, Oman, Qatar, Saudi Arabia, and the United Arab Emirates. These countries are grouped closely in the PCA space and demonstrate relatively high performance across the governance indicators. Many of them are high-income economies with stronger institutional structures, often supported by resource wealth, efficient

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public administration, or more stable political environments. Their convergence in the principal component space reflects shared characteristics of effective governance, regulatory quality, and control of corruption.

The model's uncertainty values provide further insights into the robustness of the classification. Most countries in Group 1 have uncertainty values close to zero, indicating strong model confidence in their classification. However, a few exceptions with moderate uncertainty, such as Kazakhstan (0.260), Jordan (0.196), Kuwait (0.363), and Malaysia (0.431), suggest the presence of transitional governance patterns or mixed institutional characteristics that place them near the boundary between the two groups. These intermediate cases may warrant further qualitative or temporal investigation.

3.6. Comparative Profiling of the Identified Governance Clusters:

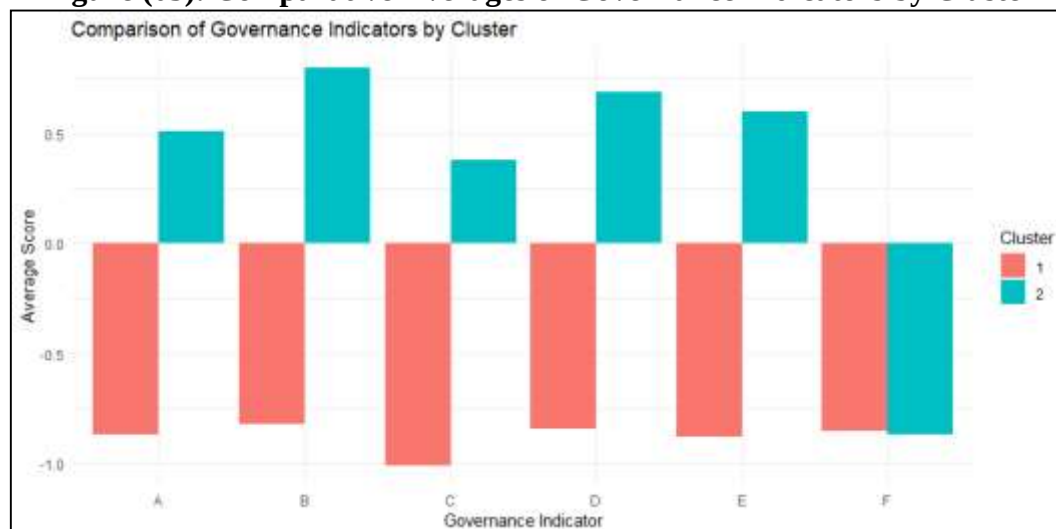
Following the classification of the 57 Islamic countries into two governance-based clusters using the MCLUST method on PCA-reduced data, it becomes essential to analyze and interpret the specific governance characteristics that differentiate these groups. This section presents a comparative analysis of the two clusters using the original standardized values of the six governance indicators. By examining the average scores for each indicator within each group, we can better understand the institutional strengths and weaknesses that define each cluster.

Table (04): Average Standardized Scores for Governance Indicators by Cluster

Cluster	1	2
Control of Corruption (CC)	-0.87	0.51
Government Effectiveness (GE)	-0.82	0.80
Political Stability (PS)	-1.01	0.38
Regulatory Quality (RQ)	-0.84	0.69
Rule of Law (RL)	-0.88	0.60
Voice and Accountability (VA)	-0.85	-0.87

Source: Prepared by the author based on the R software

Figure (03): Comparative Averages of Governance Indicators by Cluster



Source: Prepared by the author based on the R software

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The results reveal significant contrasts between the two clusters. Cluster 2, composed of only nine countries, shows notably higher average scores across five of the six governance dimensions, especially in Government Effectiveness, Regulatory Quality, and Control of Corruption. These scores indicate a relatively more robust institutional environment, more efficient public services, and higher administrative capacity. Such results are consistent with the economic and political contexts of countries in Cluster 2, many of which are wealthier, resource-rich nations with centralized state structures and investment in governance capacity.

On the other hand, Cluster 1, encompassing the vast majority of Islamic countries (48 out of 57), presents negative average values across all governance indicators. The lowest score appears in Political Stability and Absence of Violence/Terrorism, suggesting persistent challenges related to security and institutional fragility. The uniformly negative scores indicate systemic issues in public governance, potentially due to weaker rule of law, less effective institutions, and more limited regulatory environments.

A striking observation is that both clusters share similarly low values for the “Voice and Accountability” indicator. This suggests that political participation, media freedom, and civil liberties remain limited across the Islamic world, regardless of the overall governance strength.

Conclusion:

This study aimed to classify 57 Islamic countries based on their governance quality using the six Worldwide Governance Indicators (WGI) for the year 2023: Voice and Accountability (VA), Political Stability and Absence of Violence (PS), Government Effectiveness (GE), Regulatory Quality (RQ), Rule of Law (RL), and Control of Corruption (CC). These indicators were standardized and used to construct a governance profile for each country.

To reduce dimensionality and capture the main structure in the data, Principal Component Analysis (PCA) was applied. The first two principal components together explained a significant proportion of the total variance. The first component (PC1) was found to reflect a general level of institutional quality, with high positive loadings from all six governance indicators. The second component (PC2) emphasized contrasts between specific governance dimensions, particularly between control of corruption and voice and accountability.

Using the scores from PC1 and PC2, we applied model-based clustering (MCLUST) to identify homogeneous groups of countries. The Bayesian Information Criterion (BIC) indicated that the optimal model was composed of two distinct clusters:

- Cluster 1 included 48 countries characterized by lower governance performance across most indicators. These countries recorded negative scores on PC1, reflecting institutional weaknesses and lower rankings in several WGI components. They represent the majority of the Islamic world and face significant governance challenges.
- Cluster 2 included 9 countries: Bahrain, Brunei Darussalam, Jordan, Kuwait, Malaysia, Oman, Qatar, Saudi Arabia, and the United Arab Emirates. This smaller, more homogeneous cluster demonstrates relatively high performance across all governance indicators. These countries are closely grouped in the PCA space and share common features such as stronger institutional structures, effective regulatory frameworks, and better control of corruption. Many are high-income economies with stable political environments and efficient public administrations, often supported by resource wealth and long-term national planning strategies.

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The results were visualized using a scatter plot of the countries on the PCA space, and a comparative table showing the average standardized scores of governance indicators by cluster. These tools confirmed the validity of the two-group classification and highlighted the substantial disparities in governance quality among Islamic countries.

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