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Sustainable Development Performance Of Companies: A Cluster Analysis Approach

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SUSTAINABLE DEVELOPMENT PERFORMANCE OF COMPANIES: A CLUSTER ANALYSIS APPROACH

Abstract

Sustainable development can be defined as an approach where firms support economic growth while reducing environmental impacts, fulfilling social responsibilities, and adhering to strong governance principles. This study investigates sustainable development performance of non-financial companies listed on Borsa Istanbul by cluster analysis of economic, environmental, social, and governance dimensions of corporate sustainable development. Hierarchical average linkage clustering and k-means clustering are used and both result in three distinct clusters. While the economic dimension shows no significant difference between clusters, significant variations are observed in the environmental, social, and governance dimensions. To understand the characteristics of these clusters further, a comparative analysis of financial ratios, company size, and company age is undertaken. Notably, company size emerges as the sole statistically significant differentiator between the clusters. The cluster with the highest environmental, social, and governance (ESG) scores comprises larger firms compared to the others. Based on the identified sustainable development patterns within each cluster, the study proposes recommendations for enhancing their overall sustainable development performance.

Keywords: Sustainable development, Sustainable growth rate, Cluster analysis, Borsa Istanbul

FİRMALARIN SÜRDÜRÜLEBİLİR KALKINMA PERFORMANSI: BİR KÜMELEME ANALİZİ YAKLAŞIMI

Öz

Sürdürülebilir kalkınma, firmaların ekonomik büyümeyi desteklerken çevresel etkilerini azaltmayı, sosyal sorumluluklarını yerine getirmeyi ve güçlü yönetişim ilkelerine bağlı kalmayı içeren bir yaklaşım olarak tanımlanabilir. Bu çalışma, Borsa İstanbul'da işlem gören finansal olmayan şirketlerin sürdürülebilir kalkınma performanslarını; kurumsal sürdürülebilir kalkınmanın ekonomik, çevresel, sosyal ve yönetişim boyutlarının kriter olarak kullanıldığı bir kümeleme analizi ile incelemektedir. Hiyerarşik ortalama bağlantı ve k-ortalamalar kümeleme yöntemleri kullanılmış ve her iki yöntem sonucunda da üçlü kümeleme elde edilmiştir. Kümeler arasında, ekonomik boyut anlamlı bir fark göstermese de çevresel, sosyal ve yönetişim boyutlarında önemli farklılıklar gözlemlenmiştir. Bu kümelerin özelliklerini daha iyi anlamak için kümeler; finansal oranlar, şirket büyüklüğü ve şirket yaşı açısından karşılaştırmalı olarak analiz edilmiştir. Kümeler arasında sadece şirket büyüklüğü anlamlı farklılık göstermektedir. En yüksek çevresel, sosyal ve yönetişim (ÇSY) puanlarına sahip küme, diğerlerine kıyasla daha büyük firmalardan oluşmaktadır. Her kümedeki sürdürülebilir kalkınma profiline dayanarak bu çalışma, kümelerin sürdürülebilir kalkınma performanslarını geliştirmek için önerilerde bulunmaktadır.

Anahtar Kelimeler: Sürdürülebilir kalkınma, Sürdürülebilir büyüme oranı, Kümeleme analizi, Borsa İstanbul

1. INTRODUCTION

Following the promulgation of the Sustainable Development Goals (SDGs) by the United Nations in 2015, numerous countries have incorporated them into their national agendas to pursue sustainable development objectives. Turkey emerged as a frontrunner in this endeavor, ranking among the first 22 nations to submit a Voluntary National Review (VNR) at the 2016 High-Level Political Forum (HLPF). This initial VNR outlined a roadmap for SDG implementation, while the subsequent review submitted in 2019 focused on the nation's progress towards achieving these goals. Turkey demonstrably champions a holistic approach to SDG implementation and monitoring, evidenced by their integration into national Development Plans and sectoral strategies (T.C. Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı, 2019).

The United Nations' SDGs extend beyond national governments, placing significant responsibility on the private sector. Turkish businesses hold immense potential to contribute to SDG realization due to their substantial national income contributions, sizeable investments, and critical role in international trade (T.C. Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı, 2019). In essence, corporate sustainable development, defined as the extent to which businesses contribute to broader sustainability objectives (Schneider & Meins, 2012), constitutes a foundational element for national-level sustainable development. This relationship functions synergistically: businesses integrating sustainable practices into their operations can significantly enhance a nation's pursuit of sustainability goals. On the other hand, countries that actively support and incentivize corporate sustainability efforts can leverage the collective power of businesses to achieve national SDGs. Consequently, identifying areas for improvement within corporate sustainability practices is crucial. Achieving sustainable development necessitates the holistic integration of all its dimensions, economic, social, environmental, and governance, into core business activities. Therefore, a comprehensive analysis of corporate sustainability practices across these dimensions, identifying both strengths and weaknesses, is vital. Such insights would equip regulatory authorities with the necessary knowledge to develop targeted support strategies, effectively aiding businesses in their sustainability endeavors.

Motivated by the critical role of the private sector in achieving SDGs, this study focuses on companies listed on Borsa Istanbul. Notably, Borsa Istanbul was among the founding signatories of the United Nations Sustainable Stock Exchanges Initiative in 2012, underscoring its commitment to sustainability principles. Employing cluster analysis, the study groups these companies based on their performance across economic, environmental, social, and governance dimensions. This approach facilitates the creation of homogenous clusters with similar sustainable development profiles. By analyzing these clusters, the study identifies their respective strengths and weaknesses across the key pillars of sustainable development. Furthermore, the research delves into the financial aspects of these clusters, investigating potential differences in key financial ratios such as return on assets (ROA), return on equity (ROE), leverage and debt to equity ratios. These insights can inform practical and policy-oriented recommendations to support companies in both sustaining their strengths and addressing identified weaknesses.

The remainder of this paper adheres to a structured format. Section 2 provides a comprehensive review of the existing literature relevant to the topic. Section 3 outlines the research methodology employed in this study. Following the presentation of the research findings in Section 4, Section 5 delves into a detailed discussion of their implications. Finally, Section 6 offers concluding remarks and explores potential policy implications arising from the research.

2. LITERATURE REVIEW

Within academic literature, corporate sustainability, the business-level manifestation of broader sustainability goals (Özçelik & Avcı Öztürk, 2014), is frequently measured by a diverse array of proxies. Some studies evaluate sustainability performance based on inclusion or exclusion from a sustainability index (Kılıç et al., 2022; Lourenço et al., 2012; Yilmaz et al, 2020). The underlying assumption in these studies is that indexed companies exhibit superior sustainability performance compared to non-indexed counterparts. Another commonly employed proxy is the publication of sustainability reports, particularly those adhering to internationally recognized guidelines such as the Global Reporting Initiative (GRI) (Cardamone et al., 2012; Carnevale et al., 2012; Schadewitz & Niskala, 2010). While valuable for overall sustainability assessments, these approaches often neglect the evaluation of individual sustainability dimensions.

Conversely, a distinct strand of research delves into the multi-dimensionality of sustainability performance, moving beyond solely overall assessments (Khaled et al., 2021; Matuszewska-Pierzynka, 2021). However, a lack of uniformity persists regarding the specific dimensions, or pillars, employed to measure sustainability. Some studies leverage ESG scores published by authorized rating agencies like Refinitiv, Sustainalytics, and MSCI, where higher scores signify superior sustainability performance. Alternatively, other research efforts posit a three-dimensional framework encompassing economic, environmental, and social dimensions (Bansal, 2005; Chow & Chen, 2012; Özçelik & Avcı Öztürk, 2014). This divergence in dimensionality highlights the ongoing debate within the academic community regarding the most appropriate approach to measuring corporate sustainability performance.

A limited body of research explores all four dimensions of sustainable development: environmental, social, governance, and economic. Jitmaneeroj (2016) investigated the causal relationships between individual pillar scores and overall sustainability scores of global companies. His findings revealed unequal effects, with the social pillar score demonstrating the most significant influence on overall sustainability performance across the majority of industries, followed by environmental and economic performance, respectively. Notably, the governance pillar score did not emerge as the most critical factor in any industry. Furthermore, Schneider and Meins (2012) contribute to the discourse on corporate sustainability by positing that sustainability is inherently future-oriented. They argue that companies with non-continuous sustainability efforts will see limited contributions to broader sustainable development goals. Consequently, Schneider and Meins (2012) proposed a framework encompassing both current sustainability performance (economic, environmental, and social) and sustainability governance, the latter acting as a precursor to future sustainability performance. Their work highlights that while robust sustainability governance is not a sole guarantor of future success, it represents a necessary condition.

Drawing upon the aforementioned arguments, this study incorporates all four dimensions of corporate sustainable development, i.e. environmental, social, governance, and economic, into its clustering methodology to assess companies based on their overall sustainability performance. While prior research has employed clustering techniques to group companies based on various sustainability indicators, these studies often focus on a subset of the four core dimensions. For instance, Sariyer and Taşkın (2022) utilized k-means clustering to analyze companies listed on the Borsa Istanbul Sustainability Index based solely on ESG scores. Their findings revealed five distinct clusters, none of which achieved the highest performance across all pillars. Similarly, Saraswati et al. (2024) applied k-means clustering to group companies on the Indonesia Stock Exchange according to ESG pillars, demonstrating weaknesses in at least one dimension for each cluster. In contrast to this focus on ESG, Radu and Smaili (2021) employed k-means clustering to group companies listed on the Toronto Stock Exchange based on a combination of financial, social, and environmental performance indicators. Their analysis identified three distinct clusters: "financially-focused firms" exhibiting the highest financial performance but the lowest social and environmental performance, "corporate social responsibility (CSR)-focused firms" characterized by the worst financial performance but the strongest environmental and social performance, and a final cluster of "balanced performance firms" demonstrating above-average performance across all three dimensions.

A critical distinction of this study lies in its comprehensive evaluation of corporate sustainability performance, encompassing all four dimensions: economic, environmental, social, and governance. Prior research, as exemplified by the works of Sariyer and Taşkın (2022), Saraswati et al. (2024), and Radu and Smaili (2021), often focuses on a subset of these core sustainability pillars. By incorporating all four dimensions, this study offers a more holistic and nuanced understanding of a company's contribution to sustainable development. Furthermore, the clustering methodology employed in this research, which groups companies based on this comprehensive set of sustainability criteria, provides a more realistic perspective on their overall sustainability posture. This comprehensive approach has the potential to yield more targeted and effective policy recommendations compared to those derived from analyses that focus on a limited range of sustainability indicators.

3. METHODOLOGY

3.1. Sample and Data

The initial sample for this study comprised all companies listed on the Borsa Istanbul Stock Exchange (BIST ALL) that possessed both ESG scores and the requisite financial data for the year 2022, as retrieved from the Thomson Reuters Eikon database. To ensure sample homogeneity, financial institutions were excluded from this initial sample due to their distinct financial characteristics. Additionally, companies with fiscal year ends deviating from December 31st were also removed. The final sample of this study encompasses 69 firms, with a sectoral breakdown provided in Table 1.

Table 1: Sample by industry

Sector	Freq.	Percent
Basic Materials	15	21.74
Consumer Cyclicals	16	23.19
Consumer Non-Cyclicals	9	13.04
Energy	5	7.25
Healthcare	2	2.90
Industrials	11	15.94
Technology	4	5.80
Utilities	7	10.14
Total	**69**	**100.00**

3.2. Cluster Analysis and Variables

This study leveraged cluster analysis, a well-established exploratory data analysis technique (Dubes & Jain, 1980), to uncover latent patterns and group structures within the dataset (Romesburg, 2004). Stata software was employed to conduct the cluster analysis. Within Stata, two primary clustering methodologies exist: partition and hierarchical clustering. Partition clustering algorithms aim to create mutually exclusive clusters, whereas hierarchical clustering techniques generate a hierarchical structure of nested clusters. Agglomerative hierarchical clustering, a widely used approach, begins by treating each observation as an individual cluster. The algorithm then iteratively merges the two most similar clusters until all observations belong to a single cluster. Conversely, divisive hierarchical clustering starts with all observations in one group and progressively splits them into smaller, more homogenous sub-clusters (Stata, 2024).

This study adopted hierarchical agglomerative clustering as the primary method for uncovering latent structures within the data. In order to check if the chosen method influenced the results, k-means clustering, a representative of the partition clustering family, was employed as a secondary method. Within the realm of hierarchical agglomerative clustering, the average linkage method was selected due to its well-documented effectiveness across diverse scenarios and its demonstrated robustness (Kaufman & Rousseeuw, 1990). Specifically, weighted average linkage clustering, where each cluster is given equal weight in determining the distance between them for merging, regardless of the number of observations in each cluster, was implemented to group the BIST ALL companies based on their sustainability development indicators. This specific approach offers the advantage of identifying compact clusters that may vary in size, a valuable feature for this analysis (Everitt et al., 2001).

This study operationalized the four dimensions of corporate sustainable development by employing a set of relevant performance indicators. The economic dimension was proxied by the company's sustainable growth rate (SGR). Defined as the maximum rate of growth a company can achieve without depleting its financial resources (Higgins, 1977), the SGR was calculated using the following formula, consistent with several prior studies (Bagh et al., 2024; Chai et al., 2023):

$$SGR = \frac{p(1-d)(1+L)}{t-p(1-d)(1+L)} \quad (1)$$

where p denotes net profit margin on sales, d represents dividend payout ratio, L is the ratio of total debt to equity, and t stands for the ratio of total assets to net sales.

Environmental, social, and governance (ESG) performance was assessed by utilizing ESG scores retrieved from the Thomson Reuters Eikon Database. The environmental score encompasses a company's performance in resource utilization, emissions management, and environmental innovation. Social metrics incorporated into the social score include workforce composition, human rights practices, community engagement, and product responsibility. Finally, the governance score reflects a company's performance in areas such as management structure, shareholder relations, and CSR strategy. These scores range from 0 to 100, with higher scores signifying superior performance (Refinitiv, 2022).

4. RESULTS

4.1. Descriptive Statistics

Table 2 provides descriptive statistics of the whole sample. SGR represents sustainable growth rate and is calculated by the formula outlined in Equation (1). ENV, SOC, and GOV stand for environmental, social and governance scores, respectively. SIZE is the natural logarithm of total assets. ROA is the ratio of income after taxes to average total assets. LEV represents financial leverage and is calculated by dividing total assets to total liabilities. DEBTTOEQ is the ratio of total debt to total equity. AGE is the natural logarithm of number of days between the establishment of the company until 31.12.2022. The definition and measurement of variables are summarized in Table 3.

Table 2: Descriptives statistics of the sample

Variable	Obs	Mean	Std. Dev.	Min	Max
SGR	69	.269	.25	-.069	1.105
ENV	69	64.765	23.884	0	98.53
SOC	69	71.207	23.893	.479	98.195
GOV	69	51.976	22.272	5.096	88.342
SIZE	69	23.618	1.39	20.656	27.083
ROA	69	.177	.13	.001	.526
LEV	69	.599	.192	.035	.889
DEBTTOEQ	69	.932	.807	0	3.589
AGE	69	9.375	.655	7.595	10.126

Table 3: Variable definition and measurement

Variable code	Definition	Measurement
SGR	Sustainable growth rate	$SGR = \frac{p(1-d)(1+L)}{t-p(1-d)(1+L)}$
ENV	Environmental score	Thomson Reuters Eikon Database
SOC	Social score	Thomson Reuters Eikon Database
GOV	Governance score	Thomson Reuters Eikon Database
SIZE	Company size	Ln (Total Assets)
LEV	Leverage	Total Liabilities / Total Assets
ROA	Return on assets	Income After Taxes / Average Total Assets
DEBTTOEQ	Debt to equity	Total Debt / Total Equity
AGE	Company age	Number of days between the date of incorporation and 31.12.2022

4.2. Cluster Analysis Results

The initial stage of the analysis involved identifying the optimal number of clusters. To achieve this, a combination of dendrograms and cluster analysis stopping rules were employed. While numerous cluster analysis stopping rules exist, Milligan and Cooper (1985) identified the Calinski–Harabasz and Duda–Hart indices as particularly effective among the 30 rules they examined. The corresponding values for these indices are presented in Tables 4 and 5, respectively.

Given that a higher Calinski–Harabasz pseudo-F statistic signifies well-separated clusters (Stata, 2024), a three-cluster solution emerges as the most distinct clustering based on the values reported in Table 4.

Table 4: Calinski/ Harabasz values

Number of clusters	Calinski / Harabasz pseudo-F
2	69.580
3	**89.110**
4	67.210
5	61.230
6	68.610
7	62.020
8	62.490
9	68.280
10	63.240
11	66.480
12	66.780
13	65.500
14	63.120
15	60.110

On the other hand, well-defined cluster separation is typically indicated by a high Duda-Hart Je(2)/Je(1) index value alongside a low pseudo-T squared value (Milligan & Cooper, 1985). While Table 5 reveals that the eleven-group clustering exhibits the largest Duda-Hart Je(2)/Je(1) value, the minimum pseudo-T squared value is observed for the fourteen-group solution. This discrepancy, where the peak Duda-Hart Je(2)/Je(1) value and the minimum pseudo-T squared value do not correspond to the same number of clusters, prompted an examination of the three-group Duda-Hart index values. As evident from Table 5, the three-group solution boasts one of the lowest pseudo-T squared values, although not the absolute maximum Duda-Hart Je(2)/Je(1) value.

Table 5: Duda/Hart Values

Number of clusters	Duda / Hart	
	Je(2)/Je(1)	Pseudo T-squared
1	0.491	69.58
2	0.397	42.49
3	**0.453**	**7.26**
4	0.622	12.16
5	0.584	26.35
6	0.436	6.47
7	0.613	10.10
8	0.633	15.08
9	0.320	4.26
10	0.584	12.82
11	0.686	5.04
12	0.057	33.24
13	0.402	4.46
14	0.321	2.12
15	0.520	7.38

Dendrograms further serve as a visual representation of the clustering outcomes. The length of vertical lines within a dendrogram, alongside the range displayed on the (dis)similarity axis, provides insights into the strength of the clustering. Notably, longer vertical lines signify a more pronounced separation between clusters. Conversely, shorter lines indicate clusters with less distinct separation (Stata, 2024). Figure 1 presents the dendrogram generated using the weighted average linkage clustering method with Euclidean distance as the dissimilarity measure. By jointly analyzing the dendrogram and the cluster-validity indices, a three-cluster solution was determined to be the optimal number of clusters.

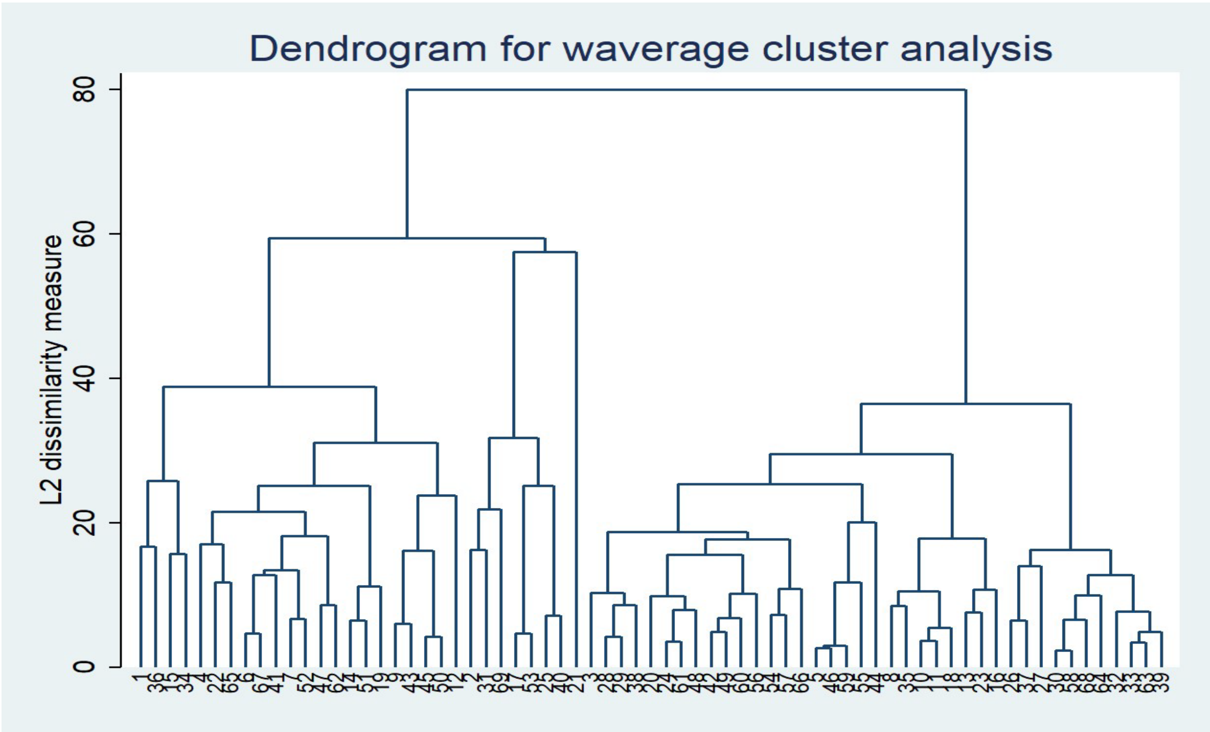

Figure 1: Dendrogram for weighted average cluster analysis

Employing the three-group weighted average linkage clustering method yielded a classification of the sample companies into three distinct clusters. These clusters consisted of 22, 8, and 39 observations, respectively. The specific firms belonging to each cluster are identified in Table 6.

Table 6: Cluster membership of the sample companies

Cluster	FIRM ID				
1	AEFES.IS	AKSEN.IS	BIOEN.IS	DESA.IS	DYOBY.IS
	GWIND.IS	ISDMR.IS	KARSN.IS	KLMSN.IS	KMPUR.IS
	KONTR.IS	KRDMD.IS	MPARK.IS	NUHCM.IS	PETUN.IS
	PNSUT.IS	POLHO.IS	SASA.IS	SOKM.IS	TTKOM.IS
	TUPRS.IS	YUNSA.IS			
2	ALKIM.IS	ANELE.IS	BASGZ.IS	BRYAT.IS	HEKTS.IS
	KCAER.IS	KOZAL.IS	SELEC.IS		
3	AKCNS.IS	AKSA.IS	ARCLK.IS	ASELS.IS	AYDEM.IS
	AYGAZ.IS	BIMAS.IS	BIZIM.IS	BRISA.IS	CCOLA.IS
	CIMSA.IS	DOAS.IS	ENJSA.IS	ENKAI.IS	EREGL.IS
	ESEN.IS	FROTO.IS	KERVT.IS	KORDS.IS	LOGO.IS
	MAGEN.IS	MGROS.IS	NATEN.IS	OTKAR.IS	PETKM.IS
	PGSUS.IS	PGSUS.IS	SISE.IS	SUNTK.IS	TATGD.IS
	TAVHL.IS	TCELL.IS	THYAO.IS	TKFEN.IS	TOASO.IS
	TTRAK.IS	VESBE.IS	VESTL.IS	ZOREN.IS	

Table 7 presents the mean values and standard deviations for the clustering criteria (SGR, ENV, SOC, and GOV scores) across the three clusters. Additionally, it compares the mean differences of these criteria between clusters. While the environmental, social, and governance scores exhibit statistically significant differences between clusters, the sustainable growth rate (SGR) does not. This finding suggests that the BIST ALL companies across the clusters demonstrate variations in their sustainability performance across environmental, social, and governance dimensions. However, their economic performance, as measured by SGR in this study, does not differ significantly.

Table 7: Descriptive statistics and Anova results of clusters

Variable	Cluster	Obs.	Mean	Std. Dev.	Pairwise Comparison of Clusters	Mean Difference (p value)
SGR	1	22	0.323	0.332	Cluster 2 & 1	-0.159 (0.379)
	2	8	0.164	0.163	Cluster 3 & 1	-0.064 (1.000)
	3	39	0.260	0.205	Cluster 3 & 2	0.095 (0.985)
ENV	1	22	54.546	13.410	Cluster 2 & 1	**-33.337 (0.000)**
	2	8	21.209	24.437	Cluster 3 & 1	**24.919 (0.000)**
	3	39	79.465	11.393	Cluster 3 & 2	**58.256 (0.000)**
SOC	1	22	65.797	14.747	Cluster 2 & 1	**-47.547 (0.000)**
	2	8	18.250	11.829	Cluster 3 & 1	**19.325 (0.000)**
	3	39	85.122	8.337	Cluster 3 & 2	**66.872 (0.000)**
GOV	1	22	40.164	10.774	Cluster 2 & 1	**-28.450 (0.000)**
	2	8	11.715	5.618	Cluster 3 & 1	**26.733 (0.000)**
	3	39	66.898	12.928	Cluster 3 & 2	**55.183 (0.000)**

Cluster 1 exhibits the highest mean value for sustainable growth rate (SGR). However, its environmental (ENV), social (SOC), and governance (GOV) scores are significantly lower compared to Cluster 3. On the other hand, Cluster 3 demonstrates the highest performance across all dimensions of sustainable development performance except the economic dimension. Notably, Cluster 2 is characterized by the lowest scores in all dimensions of sustainable development.

4.3. Additional Analysis

This section explores how the clusters differ in terms of relevant dimensions beyond the initial clustering criteria. These dimensions were identified by drawing upon existing literature on corporate sustainability performance (Ates, 2020; Li et al., 2023; Nguyen, 2024). As can be seen from Table 7, the clusters exhibit minimal differentiation across the majority of the selected dimensions. The sole statistically significant difference observed pertains to the size of Cluster 3, which is demonstrably larger than both Cluster 1 and Cluster 2.

Table 8: Additional descriptives for clusters

Variable	Cluster	Obs.	Mean	Std. Dev.	Pairwise Comparison of Clusters	Mean Difference (p value)
SIZE	1	22	23.077	1.476	Cluster 2 & 1	-0.215 (1.000)
	2	8	22.861	0.773	Cluster 3 & 1	**1.002 (0.016)**
	3	39	24.079	1.280	Cluster 3 & 2	**1.217 (0.057)**
LEV	1	22	0.582	0.187	Cluster 2 & 1	-0.068 (1.000)
	2	8	0.514	0.308	Cluster 3 & 1	0.044 (1.000)
	3	39	0.626	0.162	Cluster 3 & 2	0.112 (0.406)
ROA	1	22	0.197	0.146	Cluster 2 & 1	-0.027 (1.000)
	2	8	0.171	0.147	Cluster 3 & 1	-0.030 (1.000)
	3	39	0.168	0.120	Cluster 3 & 2	-0.003 (1.000)
ROE	1	22	0.565	0.448	Cluster 2 & 1	-0.240 (0.343)
	2	8	0.324	0.173	Cluster 3 & 1	-0.069 (1.000)
	3	39	0.496	0.337	Cluster 3 & 2	0.172 (0.685)
DEBTTOEQ	1	22	0.894	0.720	Cluster 2 & 1	-0.366 (0.820)
	2	8	0.528	0.725	Cluster 3 & 1	0.141 (1.000)
	3	39	1.036	0.858	Cluster 3 & 2	0.508 (0.324)
AGE	1	22	9.313	0.665	Cluster 2 & 1	0.273 (0.961)
	2	8	9.586	0.449	Cluster 3 & 1	0.054 (1.000)
	3	39	9.367	0.689	Cluster 3 & 2	-0.219 (1.000)

4.4. Sensitivity Test

To assess the sensitivity of the findings obtained from hierarchical agglomerative cluster analysis, k-means clustering was additionally employed. K-means clustering utilizes an iterative approach to partition data points into a user-specified number (k) of clusters. The algorithm begins by establishing k initial centroids, which represent the central points of each cluster. Data points are then assigned to the cluster with the nearest centroid. Subsequently, the centroids are recalculated based on the mean of the points assigned to each cluster. This iterative process continues until a stopping criterion is met, typically when data points remain assigned to the same clusters as in the preceding iteration (Stata, 2024).

While k-means clustering requires the user to predefine the number of clusters (k), various techniques exist to identify the optimal number of groups. Following Makles (2012), a scree plot was generated to visually assess the within-cluster sum of squares (WSS) or its logarithm (log(WSS)) for all possible cluster solutions, with the goal of identifying a elbow-kink in the curves. Additionally, the eta-squared (η^2) coefficient and the proportional reduction in error (PRE) coefficient were employed to statistically determine the optimal number of clusters. The calculated statistics and the corresponding scree plots are presented in Table 9 and Figure 2, respectively.

Table 9: WSS, log(WSS), η^2, and PRE statistics for all K cluster solutions

k	WSS	Log(WSS)	eta_squared	PRE
1	111345.00	11.62	0.00	.
2	45067.44	10.72	0.60	0.60
3	29485.10	10.29	0.74	0.35
4	23698.13	10.07	0.79	0.20
5	19969.49	9.90	0.82	0.16
6	15972.35	9.68	0.86	0.20
7	13539.57	9.51	0.88	0.15
8	13872.03	9.54	0.88	-0.02
9	10494.30	9.26	0.91	0.24
10	9966.27	9.21	0.91	0.05
11	9279.01	9.14	0.92	0.07
12	7641.99	8.94	0.93	0.18
13	6894.40	8.84	0.94	0.10
14	6701.71	8.81	0.94	0.03
15	6317.27	8.75	0.94	0.06
16	6076.34	8.71	0.95	0.04
17	5502.23	8.61	0.95	0.09
18	5247.25	8.57	0.95	0.05
19	4790.35	8.47	0.96	0.09
20	5025.97	8.52	0.95	-0.05

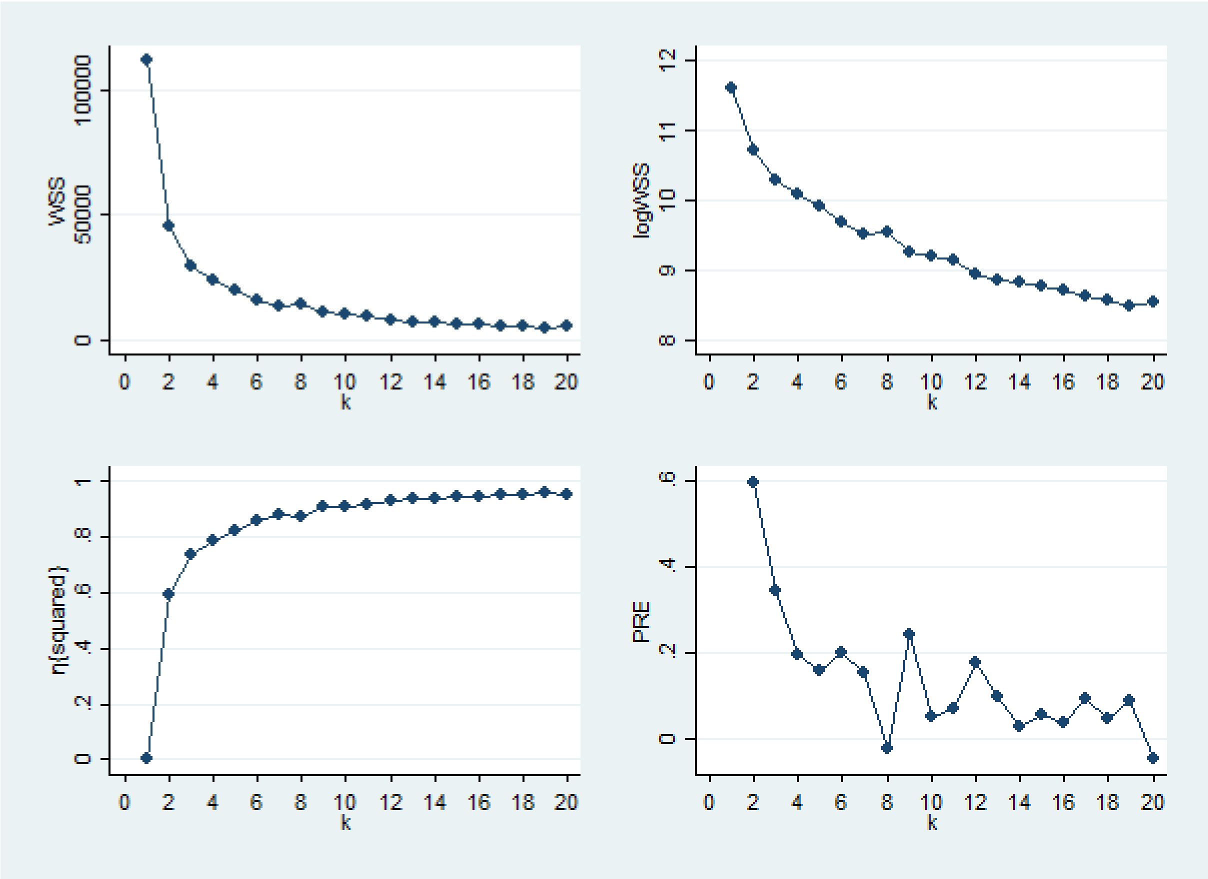

Figure 2: Scree Plots of WSS, log (WSS), η^2, and PRE for all K cluster solutions

Both the WSS and log (WSS) plots exhibit a pronounced elbow at k = 3. Beyond this point, the decrease in WSS and log (WSS) becomes markedly slower, suggesting that further cluster divisions yield diminishing marginal returns in terms of explained variance. The η^2 coefficient (η^2_3) indicates a 74% reduction in WSS compared to the k = 2 solution, with the PRE coefficient (PRE_3) revealing a corresponding reduction of approximately 35%. Notably, the decrease in WSS becomes negligible for k > 3. Collectively, these findings suggest that k = 3 represents a reasonable choice for the number of clusters.

Following the identification of k = 3 as the optimal number of clusters, a k-means cluster analysis employing Euclidean distance as the dissimilarity measure was conducted. This procedure resulted in the classification of firms into three distinct clusters with 20, 10, and 39 observations, respectively. Details regarding the firm composition within each cluster are presented in Table 10.

A comparative analysis of the cluster compositions generated by the weighted average linkage and k-means clustering methods is presented in Table 11. The only observed discrepancy in firm membership pertains to BIOEN.IS and DESA.IS. These firms were classified within Cluster 1 using the weighted average linkage method, while the k-means clustering results assigned them to Cluster 2.

Table 10: Cluster Membership of the Sample Companies (K-means Clustering)

Cluster	FIRM ID				
1	AEFES.IS	AKSEN.IS	DYOBY.IS	GWIND.IS	ISDMR.IS
	KARSN.IS	KLMSN.IS	KMPUR.IS	KONTR.IS	KRDMD.IS
	MPARK.IS	NUHCM.IS	PETUN.IS	PNSUT.IS	POLHO.IS
	SASA.IS	SOKM.IS	TTKOM.IS	TUPRS.IS	YUNSA.IS
2	ALKIM.IS	ANELE.IS	BASGZ.IS	**BIOEN.IS**	BRYAT.IS
	DESA.IS	HEKTS.IS	KCAER.IS	KOZAL.IS	SELEC.IS
3	AKCNS.IS	AKSA.IS	ARCLK.IS	ASELS.IS	AYDEM.IS
	AYGAZ.IS	BIMAS.IS	BIZIM.IS	BRISA.IS	CCOLA.IS

CIMSA.IS	DOAS.IS	ENJSA.IS	ENKAI.IS	EREGL.IS
ESEN.IS	FROTO.IS	KERVT.IS	KORDS.IS	LOGO.IS
MAGEN.IS	MGROS.IS	NATEN.IS	OTKAR.IS	PETKM.IS
PGSUS.IS	PGSUS.IS	SISE.IS	SUNTK.IS	TATGD.IS
TAVHL.IS	TCELL.IS	THYAO.IS	TKFEN.IS	TOASO.IS
TTRAK.IS	VESBE.IS	VESTL.IS	ZOREN.IS	

Table 11: Comparison of cluster memberships between weighted average and K-means clustering

	Weighted Average		
K-means	**1**	**2**	**3**
1	20		
2	2	8	
3			39

5. DISCUSSION

The cluster analysis of BIST ALL companies based on their sustainable development performance revealed a pattern of homogeneity in economic dimension, as measured by sustainable growth rate (SGR), across the identified clusters. Conversely, significant heterogeneity was observed in the environmental, social, and governance dimensions of sustainable development performance. These findings suggest a potential decoupling between a company's economic performance, as reflected by SGR, and its performance in ESG issues. This implies that strong economic performance (high SGR) might not necessarily translate to strong environmental, social, or governance practices. This argument is further bolstered by the additional analysis, which demonstrated no statistically significant differences in key financial ratios (e.g., financial leverage, return on assets, return on equity, debt-to-equity ratio) between the clusters generated by the cluster analysis. Collectively, these results suggest that companies' focus on ESG issues might be driven by factors beyond purely economic considerations.

The additional analysis conducted in section 4.3 revealed a statistically significant difference in the mean size of the clusters. Cluster 3 exhibited a demonstrably larger size compared to both Cluster 1 and Cluster 2. Notably, Cluster 3 also displayed the highest mean values for all three dimensions of ESG performance. When considered jointly, these findings suggest a potential association between company size and its focus on ESG issues. Larger companies within Cluster 3 might prioritize addressing environmental, social, and governance concerns due to their heightened public visibility. This observation aligns with the results reported by Sariyer and Taşkın (2022), who identified a similar trend where the cluster with superior environmental and social scores comprised larger firms.

In summary, the cluster analysis revealed distinct profiles among BIST ALL companies regarding their sustainable development performance. Cluster 2, characterized by the lowest scores across all environmental, social, and governance (ESG) dimensions, necessitates targeted interventions to improve its sustainability practices. Cluster 1, while exhibiting the highest sustainable growth rate, presents an opportunity for enhanced focus on ESG considerations. Finally, Cluster 3, although demonstrating leadership in ESG performance, could benefit from further efforts to strengthen its economic sustainability for optimal overall performance

6. CONCLUSION

This study investigated the sustainable development patterns of the BIST ALL companies using cluster analysis. Companies were grouped based on their performance across all four dimensions of sustainable development: economic, environmental, social, and governance (ESG). By adopting this comprehensive approach, it is aimed to provide a holistic view of each company's sustainability efforts. Sustainable growth rate served as a proxy for economic performance, while ESG scores sourced from Refinitiv were used for the remaining dimensions.

Both the primary research method (weighted average linkage clustering) and the sensitivity tests (k-means clustering) identified three distinct clusters of the BIST ALL companies exhibiting unique sustainable development performance profiles. The most noteworthy finding was the observed disparity between economic performance and ESG practices across the clusters. This disparity is characterized by insignificant differences in sustainable growth rate (a proxy for economic performance) but significant differences in the ESG scores of the clusters. This suggests a potential decoupling between a company's economic health and its commitment to ESG principles. Further analysis revealed no significant differences in key financial ratios (e.g., financial leverage, return on assets, return on equity, debt-to-equity ratio) between the clusters, further supporting this notion. Collectively, these findings suggest that ESG performance in BIST ALL companies may not be directly linked to their current economic standing. Company size emerged as a potential factor influencing ESG behavior, as Cluster 3, with the highest ESG scores, also comprised significantly larger firms compared to the other clusters.

To explore practical and policy implications, the cluster profiles were analyzed based on each clustering criterion. Cluster 2 displayed the weakest overall sustainable development performance due to consistently low scores across all dimensions. Companies within Cluster 2, representing approximately 12% of the sample, necessitate targeted interventions to enhance their sustainability practices in all areas. Conversely, Cluster 1, while exhibiting the highest sustainable growth rate, displayed only average scores for ESG dimensions. This finding suggests an opportunity for Cluster 1 companies to prioritize and improve their environmental, social, and governance consciousness. The majority of companies (56.5%) reside in Cluster 3, demonstrating superior ESG performance but a lower sustainable growth rate compared to Cluster 1. To solidify and enhance their leadership in ESG, companies in Cluster 3 could focus on strengthening their economic sustainability. Cluster 2, exhibiting a higher sustainable growth rate than Cluster 3 but lower ESG performance, suggests a potential neglect of ESG considerations. Companies within Cluster 2 should prioritize integrating ESG practices for a more holistic approach to sustainable development.

The findings also offer valuable insights for investors and policymakers. The divergence between economic performance and ESG practices highlights the need for a balanced evaluation of both dimensions when making investment or policy decisions. Cluster 3 companies, with strong ESG performance but lower sustainable growth rates, may appeal to ESG-focused investors seeking long-term potential. Cluster 1, with high economic growth but average ESG scores, underscores the importance of improving sustainability practices to mitigate potential risks. Meanwhile, Cluster 2 companies, which underperform across all dimensions, require targeted strategies to enhance their overall sustainability efforts. These insights emphasize the importance of aligning economic and ESG objectives for sustainable growth.

This study acknowledges several limitations. Firstly, the selection of proxies to measure sustainable development performance could influence cluster composition. Exploring alternative proxies may yield different cluster structures. Secondly, utilizing cross-sectional data for clustering limits generalizability. Employing panel data in future research may offer more comprehensive insights into the evolving sustainable development patterns of companies. Addressing these limitations through future studies can contribute significantly to the existing body of knowledge. Additionally, future research endeavors could extend the profile analysis of the clusters by incorporating other relevant company characteristics, such as specific governance structures.

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