



A Robo-Advisory Framework for Islamic and Environmental, Social and Governance (ESG) Compliance – A Benchmark Study on the S&P 500 Stock Index

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ABSTRACT - The last decade has brought a revolution in the financial sector, enabling more individuals and institutions to access the stock market. Islamic finance has similarly gained considerable interest from the growing Muslim population that is looking for Shariah-compliant investment options. Furthermore, a growing number of investors are looking for investment options that are environmentally sustainable and adhere to ethical values. While there are various Shariah advisory services, these services differ widely in their assessments of whether a company is Shariah-compliant. Given the cost of these services, it is typically only available for large institutional investors. The objective of this article is to address the challenges of providing individualized Shariah-compliant investment services automatically while providing a comparison with Environmental, Social and Governance (ESG) compliance to assist both investors who are seeking Shariah and ESG compliant investments. Hence, the study presents a new unsupervised learning framework for the determination of Shariah compliance and evaluates it with ESG compliance. The framework first filters the companies based on whether they have any exclusionary activities and then performs a clustering approach in order to classify them into compliant and non-compliant stocks. The framework was evaluated on the S&P 500 stock index and delivered acceptable and reasonable classifications. This Robo-Shariah advisor framework allows automatized real-time Shariah compliance evaluation based on a data-driven approach. The practical implication of this new framework is the enablement of objective, data-driven Shariah-compliant investment recommendations that can be easily integrated with Shariah expert information. The social implication is the empowerment of retail investors in being able to easily set up their own Shariah-compliant portfolio.

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INTRODUCTION

The members of the Organization of Islamic Cooperation (OIC) have experienced significant growth over the last fifty years. The share of GDP is unevenly distributed amongst the member nations, with Indonesia accounting for 15 %, followed by Turkey with 10% and Saudi Arabia with 10.2 %. Specifically, the five largest economies account for more than 50 % of the GDP of

these nations (SESRIC, 2021). While the COVID-19 pandemic has hit several of these economies rather hard, massive stimulus by the central banks of many Islamic countries has softened its direct impact. The total GDP of the OIC member countries has declined from 7.3 trillion USD to 6.9 trillion USD from 2019 to 2020. By 2021, the increased stimulus is expected to lead to a GDP of 7.7 trillion (SESRIC, 2021). In these countries, both individuals from the middle class and different institutions now consider investment in the stock market as a licit way of increasing wealth. With the growing development and availability of investment products and stockbrokers, such as Robinhood, Revolut, and others, stock investment products are more and more available. The combination of a search for liceity—in the Islamic sense—and the democratization of access to financial markets explain why these countries have experienced a resurgence on accessible financial products that adhere to the principles of Islam (Alam et al., 2017).

The level of sophistication has also increased. Islamic finance keeps growing in the area of modern international finance. Modern Islamic banking and finance concepts started in Pakistan. They developed in the 1960s in Egypt, where the Mit-Ghamr Islamic Saving Associations provided savings products to Muslim investors that adhered to Shariah law (Schoon, 2008). This attracted significant deposits and led to a massive rise in deposits in the first years of operation. Malaysia followed in providing Shariah-compliant savings instruments for future pilgrims to cover their expenditures during their Hajj pilgrimage. The products were driven by Pilgrims Fund Corporation and it achieved deposits of more than 12 billion USD and had more than eight million account holders. Islamic banking rose to prominence in the 1970s with the establishment of several institutions that grew to more than 2 trillion USD up to now (Askari et al., 2012). The establishment of the Islamic Development Bank (IDB) was a major milestone after the establishment of the Dubai Islamic Bank in the United Arab Emirates. Pakistan was one of the first countries to overhaul its entire banking system to comply with Shariah principles which led to the introduction of profit-sharing financing companies that adhered to Shariah. Furthermore, Iran introduced a new banking law that implemented interest-free banking and forced all banks to comply with these regulations (Moisseron et al., 2015; Ahmad et al., 2020).

On the regulatory side, another important milestone was the establishment of an organization that aimed to establish standards for Islamic Financial Institutions. This is the Account and Auditing Organization for Islamic Financial Institutions (AAOIFI). It aims to unify accounting and auditing as well as Shariah standards for financial reporting. Malaysia has been at the forefront of the development of supervisory and regulatory standards and guidelines to determine which financial instruments are Shariah-compliant and what specific instruments, such as stocks, need to be fulfilled in order to adhere to the Shariah law. While there has been significant progress in this regard, there are still significant variations in determining which financial instruments are Shariah-compliant or not (Mawdudi, 2011; Abu Seman et al., 2021). There is currently a lack of a comprehensive regulatory framework that is uniformly accepted to specify the criteria on which a company may be Shariah-compliant. Furthermore, a balance needs to be struck in order to ensure sufficient numbers of assets are available for investment while maintaining compliance with Shariah.

Scholars have reached a strong consensus on factors pertaining to the underlying asset, such as the prohibition of some activities (e.g., gambling, alcohol, tobacco) or sectors (e.g., pornography, pork production) or activities (Mohamed & Ali, 2018). At the same time, they are still debating other factors pertaining to the behavior of the stock (e.g., the exclusion of a purely speculative asset). This debate is at the center of Islamic economics, with the Shariah Law mandating that productive human activity is the essence of the value generation process. Therefore, there is a need for clarification and unification of the Shariah compliance of investment available to the Islamic public.

The objective of this article is to provide a Shariah-compliant robo-advisory framework for retail investors in order to optimize both their Shariah in addition to ESG compliance. The framework enables to classify both ESG and shariah-compliant stocks utilizing a data-driven approach. This enables AI-assisted decision-making for retail investors in terms of determining whether stocks are Shariah and ESG compliant. Furthermore, this article is to outline a new unsupervised learning approach for classifying Shariah and ESG compliant companies. The framework analyzes various company parameters in addition to news information of the company and then clusters the companies into compliance and non-compliance. The framework allows to easily classify companies based on various available financial and textual information, therefore providing a recommendation engine for the determination of Shariah and ESG compliance.

LITERATURE REVIEW

Exchange-traded funds have become a cornerstone of modern investment, allowing individuals to invest in funds that are publicly traded on the stock exchange. Exchange-traded funds (“ETF”) can be traded throughout the day on the stock exchange and differ from mutual funds that can be bought or sold only once a day (Lettau & Madhavan, 2018). The exchange-traded funds are divided into shares that are held by shareholders. The fund purchases the specified assets on the stock exchange, and the shareholders implicitly own these assets. Recent years have led to the growth of several Islamic ETFs that invest in stocks that must adhere to specified Islamic criteria as per Shariah law (Mohamed & Ali, 2018).

A key challenge for the Shariah-compliant investment into stocks is the lack of universal criteria for assessing whether a corporation is compliant or not. The S&P 500 Shariah Index provided by Dow Jones is based on a collaboration with Ratings Intelligence Partners that specializes in the assessment of Shariah-compliant assets and work directly together with a supervisory board of five Islamic scholars (S&P Dow Jones Indices, 2021). However, this statement and the criteria may be subject to interpretation and requires extensive manual assessment of stocks in terms of whether they are compliant (El-Komi & Croson, 2013). In contrast to this, Morgan Stanley Capital International (“MSCI”) stipulates the requirements in its requirements, such as for the MSCI World Islamic Index. The ETF follows Shariah principles and does not allow any investment into companies that either actively or passively obtain more than 5 % of their business revenues from business activities such as alcohol, tobacco, pork-related products, conventional services, defense/weapons, or gambling and adult entertainment. This criterion primarily excludes companies that are actively engaged in these activities but may include corporations that are still partially involved in these activities, such as hotels that provide some gambling options. The MSCI index further requires that the invested companies do not obtain a significant income from interest or have excessive leverage. In order to screen stocks through this filter, three financial ratios are utilized. These are 1) total debt over the total asset, 2) the sum of cash and interest-bearing securities relative to the total assets, and 3) the sum of the accounts receivables and cash to the total assets. All of these financial ratios shall be less than one-third, and any derived income from interest or prohibited activities has to be deducted and given to charity (Hassan, 2017) as remediation.

In addition to this traditional negative screening technique, Islamic investors are now interested in a positive analysis of the potential investments: Environmental, Social, and Governance (ESG) compliance. ESG has come to the forefront in the last two decades given the spate of corporate frauds—e.g., Enron—, human rights abuses, and economic failures—e.g., Lehman Brothers. The concept of ESG investment is not new. It has been

engrained in Islamic values and morals for centuries. Conventional finance has only recently taken notice of the importance of these values in order to target a new investor base and avoid the unethical behavior of companies and their management (Amel-Zadeh & Serafeim, 2018). The motivation is a moral one. It posits that these ESG factors will positively affect the long-term financial performance of companies. The challenge is to reconcile the short-term orientation of traditional financial markets with the long-term view of ethical sustainability.

ESG investment has a long history whose origin can be found at biblical times where investments based on moral values were already emphasized (Amel-Zadeh & Serafeim, 2018). At qur'anic times, a strong codification of investments and finance took place, based on ethical values that include both society and the environment. Furthermore, a strong emphasis on the connection between the market value of the investment product and real assets was laid. The United States experienced in the eighteenth century its first wave of morality-based investment with the Methodists. The Quakers followed the same trend by refusing to invest in companies that sold liquor or engaged in gambling. In contrast to Islamic finance, these investment forms were rather fringe investment operations that were largely ignored by the general investment community (Kotsantonis et al., 2016). The 1960s brought some changes with the ongoing war in Vietnam, where protestors demanded that the university endowments exited investments in defense contractors. Nuclear disasters in the 1980s led to a growing focus on environmental factors in the investment communities. More recently, the apartheid in South Africa was another impetus for socially responsible investing. Many individuals requested that corporations embargo business and investment with South Africa as a way of ending apartheid.

With the growing ability of individuals to invest directly into the stock market and having more investment options available to them, ESG investment has become more important in recent years. The COVID – 19 pandemic has strengthened this trend. At the end of 2020, almost 30 trillion USD are being allocated to sustainable investment funds. This number could even grow by more than 20 trillion USD in the next decades, given the growing focus on the environment and social responsibility (Broadstock et al., 2021).

While there are several funds that are providing services and allowing investors to invest in certain types of corporations, determining which company is ESG compliant is a challenge. Furthermore, ESG compliant corporations are also Shariah-compliant and vice versa (O'Leary & Hauman, 2020).

Conventional compliance assessments take a variety of different factors but determining whether stocks are Shariah or ESG compliant differs wildly between different assessors and categories. Furthermore, most of the assessment is conducted based on manual assessments and data analysis, thereby leading to potentially considerably different assessments for the same stocks. The differences may arise in terms of how corporate activities are assessed in terms of their overall impact on ESG factors (Dye et al., 2021). For example, a company that invests in the extraction of natural gas may be either assessed as an environmentally friendly entity that aims to reduce its overall carbon footprint or as a fossil fuel user that may cause damage to the environment. Even renewable energy companies may face challenges. For example, solar energy companies may be considered ESG compliant companies, but depending on where they acquire the solar panels, this may make them even stronger emitters as compared to other comparable energy companies. This outlines the importance of having a data-driven and standardized approach to define compliance and improve comparability.

METHODOLOGY

We have developed a new unsupervised learning framework for the Shariah and ESG compliance of companies. The framework (Figure 1) integrates stock market data, financial data, and sustainability parameters in addition to news and other textual information about the company into a robo-engine framework and subsequently clusters the stocks according to ESG and Islamic finance compliance. As outlined previously, ESG and Islamic finance compliant companies may differ from a bank that provides interest-based loans that may be ESG compliant but not Islamic finance compliant. Furthermore, a corporation that provides halal slaughtered meat may be Shariah-compliant, but not ESG compliant if its carbon footprint is deemed too significant. This outlines the importance of considering these two categories as separate for the sake of classification. The Robo-Compliance engine first determines, based on various factors, such as business sector, products, services offered, and others, whether there is any automatic clustering criterion. For example, a company in adult entertainment or gambling, such as Wynn Casinos, will be automatically regarded as Shariah non-compliant irrespective of any subsequent clustering similarities. Likewise, a company is non-ESG compliant if it is producing warcraft and arms actively for conflicts.

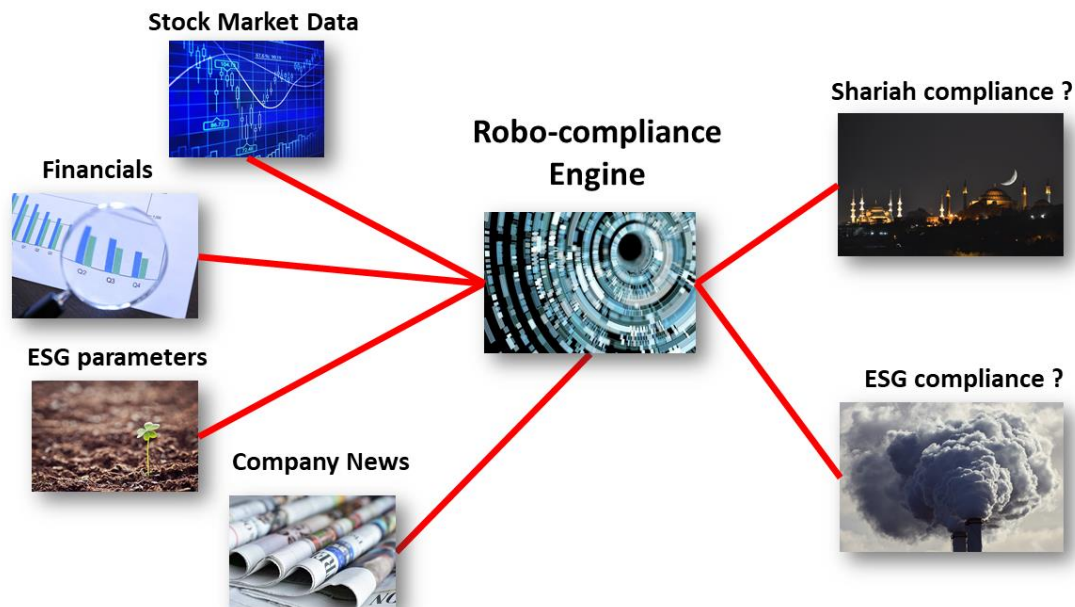


Figure 1: Robo-Compliance Engine

Based on the initial categorization of non-compliant stocks and stocks to be further evaluated, we then performed clustering on the remaining stocks. For the clustering, we utilized several clustering algorithms such as the K-Means, k-median, Gaussian Mixture Models, hierarchical clustering, and spectral clustering.

K-Means Clustering

The K-Means clustering is a vector quantization method that partitions n observations into k clusters where each of the observations belongs to the cluster with the nearest mean. The means are also denoted as the cluster centers. The k-means algorithm is relatively simple to utilize and implement but faces several challenges in that it may easily converge to a local minimum, and obtaining the optimal solution is an NP-hard challenge (Likas et al., 2003).

K-Mediod Clustering

The K-Medoid problem is similar to the k-means clustering technique, except that the means are replaced by the medians of the centers. The median may be more suitable for problems where the input data have a considerable number of outliers which would distort the means and make them very susceptible to outliers (Harikumar & Surya, 2015).

Gaussian Mixture Models

Gaussian mixture models focus on the data in a different way, assuming that there are a certain number of Gaussian distributions. These data are then assigned depending on whether they belong to the same Gaussian distribution. The difference between Gaussian mixture models and k-means is that the probabilistic form of the method provides only a soft assignment of the classes as compared to k-means approaches (Emerson et al., 2019).

Hierarchical Clustering

Hierarchical clustering builds nested clusters via the merging or splitting of them into successive steps. The hierarchy of a cluster is represented as a tree, and the root of the tree is the unique cluster gathering all the samples. The leaves represent the clusters with only a single sample. Hierarchical clustering may have different strategies that involve ward and single, average and complete linkage.

Spectral Clustering

Spectral clustering utilizes a low-dimension embedding of the affinity matrix between the samples and then utilizes clustering in order to assign them to the specified clusters. The algorithm is rather efficient and works well for a small number of clusters. For two clusters, the spectral clustering algorithm solves the convex relaxation of the normalized cuts problem on the similarity graph.

Clustering results obtained from the various algorithms may differ for the respective data. However, the performance for each of the algorithms is outlined by several metrics such as the silhouette score or the rand index, which computes the similarity measure between two clusters. The problem with the rand index is that it requires information about the true labels, which are not available for conventional clustering problems. Hence, the silhouette score, as well as the additional performance metric scores Calinski Harabasz as well as Davies Bouldin index, are the only ones suitable for the evaluation.

The selection of the features for ESG and Shariah compliance represents a critical role. Specifically, ESG and Shariah compliance may depend on different features and correlations. While a high PE ratio may not significantly impact ESG compliance, it may be significant for Shariah compliance as it indicates a speculative or fictive evaluation of the company.

RESULTS

We evaluated the framework on the SP500 index constituents. The S&P 500 Index or Standard's & Poor 500 index is a market capitalization-weighted index of the 500 major stock-listed enterprises in the United States. The companies are not entirely selected based on the market capitalization as there are other criteria that are utilized to determine the constituents. The S&P 500 index is a highly regarded stock index, which solely focuses on free-floating shares for the calculation of the market cap. The S&P 500 index is a major index based on which many funds and individuals select their investments. Given the large market capitalization of most of these corporations and wide availability across the world, many individual and institutional investors invest in these corporations. For Muslim

investors, it can be a challenge to determine whether indexed corporations fulfill the criteria to be permissible to Muslim investors. Given the variety of different business sectors, financial performances, and business models, determining the compliance of individual corporations is complex. Furthermore, there is a difference between ESG and Shariah compliance. While an alcohol-producing company may be compliant in terms of ESG, the same corporation is definitely not compliant according to Shariah law.

All constituent data for the S&P 500 were extracted from Yahoo Finance's API for the year 2021. There was a low percentage (less than 1 %) where the data were not fully complete, and the data were manually augmented with publicly available information. The Robo-Compliance engine initially filters the data in terms of clear criteria for both ESG and Shariah Law. For Shariah compliance, any corporation that is active in gambling, adult entertainment, or is active in the distribution of alcoholic or pork products or services can be immediately considered to be non-compliant. These data were readily available via the API interface and could be readily retrieved. Similarly, ESG compliance was determined based on whether the corporation has any military contracts, distributes arms, or is in the development of controversial weapons involved, as well as invests into coal. When comparing the differences, one can easily observe that companies such as General Electric may qualify to be Shariah-compliant while not being compliant in terms of ESG. This is because General Electric still has considerable investments in coal power plants, which are not acceptable according to ESG parameters, but acceptable in terms of Shariah Law.

Likewise, corporations such as Molson Coors Beverage Company may be ESG compliant but are definitely not Shariah-compliant as they are selling alcoholic beverages.

Filtering these corporations from the dataset is critical as the information derived from these data may not be represented in the remaining data categories and would bias the clustering results. Two corporations may have identical financial and other textual performance data but may differ in terms of their Shariah or ESG compliance.

With the remaining datasets, we then evaluated the clustering effect for both ESG and Shariah compliance. We first evaluated the overall quality of the clustering algorithms in being able to cluster the data adequately and exclude any algorithms whose performance is unsatisfactory. Hierarchical clustering seemed to perform very poorly, as outlined in Error! Reference source not found.. The clusters are unevenly distributed, with the majority belonging to Shariah-compliant (blue) stocks. Such a clustering model would ill-represent the data and provide improper advisory.

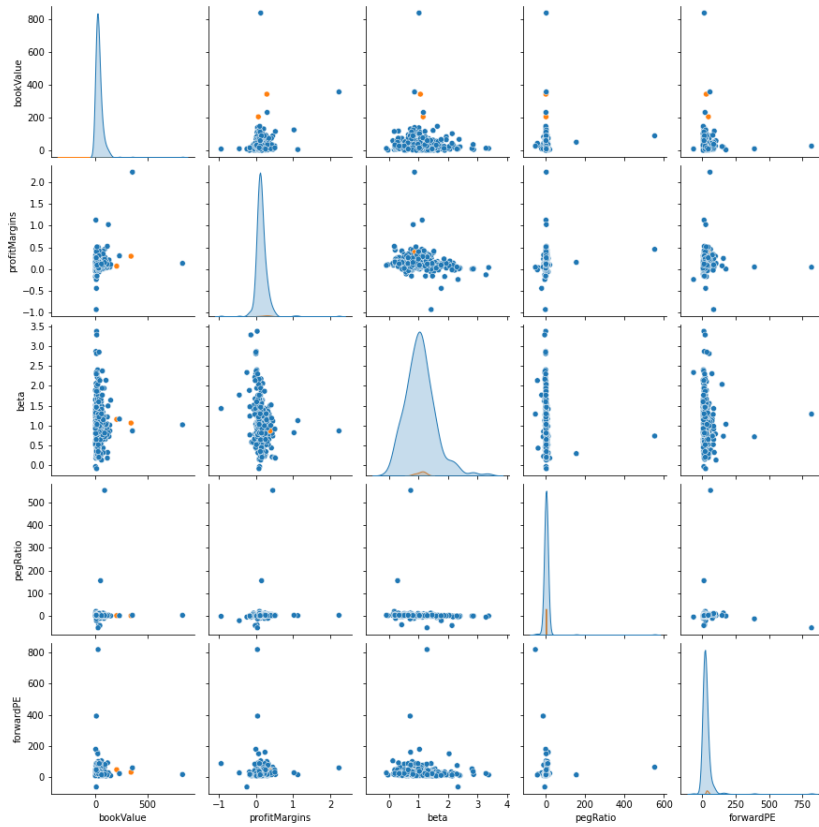


Figure 2: Hierarchical Clustering for the Determination of Shariah Compliance

Having determined that hierarchical clustering has performed poorly to distinguish compliance, we have evaluated the other techniques in order to determine clusters to distinguish compliance from non-compliance. We outline in **Error! Reference source not found.** and Figure 2 the results from utilizing spectral clustering. Spectral clustering utilizes the spectrum of the similarity matrix of the data in order to first, reduce its dimensions and then subsequently cluster the data. Both figures demonstrate some reasonable clustering effects that outline the points in orange to be Shariah non-compliant while the data points in blue are Shariah-compliant. High book valuations in contrast to low peg ratios typically outline that the company has a strong balance sheet and assets and limited overvaluation of its stock. The peg ratio is the ratio of the stock price to earnings (PE) ratio and the earnings growth over a specified time period, and a high PE ratio, while having limited earnings growth represents conventionally a speculative asset that may not be Shariah-compliant.

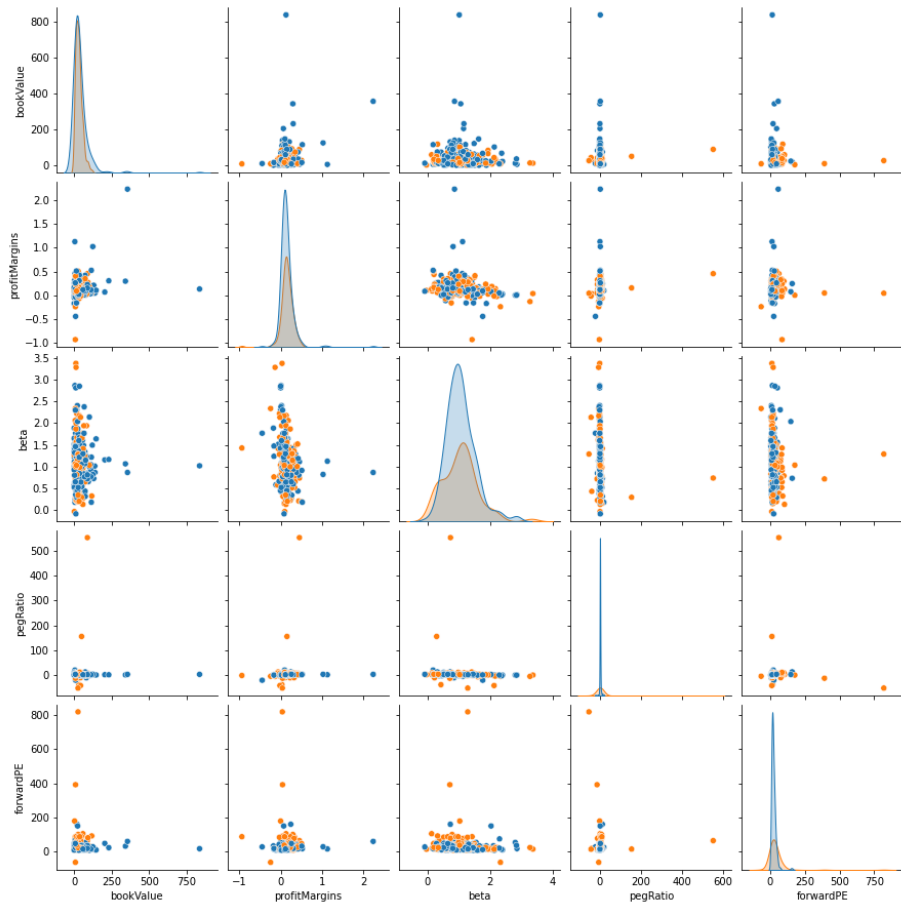


Figure 3: Shariah Compliance Cluster Comparison for Spectral Clustering

Comparing the clusters for the ESG compliance, one can observe a similar clustering behavior. Blue data points indicate ESG compliance, while orange data points indicate non-ESG compliance. Specifically, high forward PE may imply rather speculative and potentially lead to significant losses for investors as these growth rates are not sustainable over the long term.

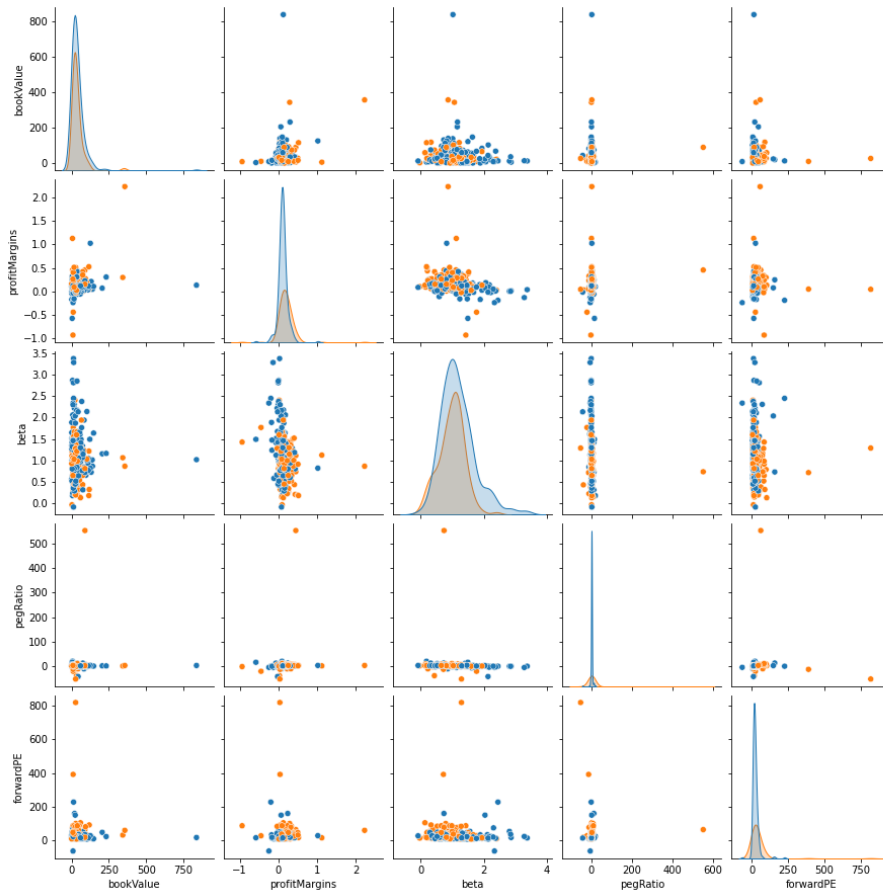


Figure 2: ESG Compliance for Spectral Clustering

We evaluated with various clustering performance metrics the quality of the algorithms in distinguishing the data with respect to their compliance. Performance metrics evaluate the quality of the clusters being well distinguished and separable, but the parameters have to be carefully analyzed given heavily biased clusters may have a high score but fail to properly cluster the data. The silhouette clustering is a measure to determine the goodness of clustering. The performance values are within the range between -1 and 1, where -1 implies that the clusters are wrongly clustered, while 1 implies a perfect clustering performance. The Calinski-Harabasz Index is based on the ratio between the cluster's dispersion and the inter-cluster dispersion and is another criterion to evaluate the performance of the clustering technique. The higher the ratio, the better the clustering performance. The Davies-Bouldin index estimates the average similarity between clusters and compares the distance between the clusters to the size of the cluster. While relatively simple, the score may provide some critical insight but is limited to Euclidean distances. The lower the index is, the better is the separation between the clusters. It is essential to carefully analyze the scores and input data, as abnormalities such as agglomeration may lead to poor clustering, although the score is high. We present in Error! Reference source not found. the Calinski-Harabasz scores for both the Shariah and ESG compliance. As can be observed, K-Means and spectral clustering have the best performance in being able to distinguish between the clusters in terms of compliance and non-compliance. Generally, the above scatter plots have outlined that spectral and k-means clustering have performed rather well in providing reasonable compliance clustering

Table 1: Comparison of the Calinski-Harabasz Scores for All Algorithms and ESG and Shariah Compliance

Calinski-Harabasz	Shariah Compliance	ESG Compliance
K-Means	64.66764	54.8807
K-Medoid	56.76574	47.27096
Gaussian Mixture Model	39.6784	34.75546
Agglomerative Clustering	16.00846	17.41484
Spectral Clustering	62.25956	54.48563

Comparing in Table 2 and Table 3 the performance metrics for both Shariah and ESG compliance for the various algorithms, both K-Means and Spectral clustering perform reasonably well. Most other models perform similarly well, except for the agglomerative clustering that, despite having a high Silhouette and Davies-Bouldin score, cluster the corporations into highly unevenly distributed clusters. For example, in the case of Shariah compliance, only large corporations such as Amazon, Apple, and Alphabet are compliant, which is a very strict interpretation of compliance and demonstrates poor performance to accurately capture the clusters. This contrasts with other algorithms that lead to more evenly distributed clusters differentiating between Shariah and ESG compliance well.

Table 2: Comparison of Performance Metrics for Shariah Compliance

Shariah	Silhouette	Calinski Harabasz	Davies Bouldin
K-Means	0.152352	64.66764	2.140798
K-Medoid	0.139134	56.76574	2.214682
Gaussian Mixture Model	0.175367	39.6784	2.924555
Agglomerative Clustering	0.43486	16.00846	0.912954
Spectral Clustering	0.150281	62.25956	2.202155

Table 3: Comparison of Performance Metrics for ESG Compliance

ESG	Silhouette	Calinski Harabasz	Davies Bouldin
K-Means	0.136691	54.8807	2.207458
K-Medoid	0.129719	47.27096	2.227904
Gaussian Mixture Model	0.10927	34.75546	2.955779
Agglomerative Clustering	0.4527	17.41484	0.896458
Spectral Clustering	0.138084	54.48563	2.260094

CONCLUSION

We have presented a new innovative unsupervised learning framework for the determination of Shariah and ESG compliance of stocks. The framework integrates a rules-based filtering approach followed by an unsupervised clustering algorithm in order to cluster both compliant and non-compliant stocks. The framework was evaluated on the S&P 500 stock index data with reasonable results. It provides a valuable and data-driven approach to robustly classify stocks in terms of their ESG and Shariah compliance, as well as enhances consistency in the selection via the avoidance of potential biases incurred by manual human interpretation and judgment.

REFERENCES

- Abu Seman, J., Jamil, N. N., & Mohd Hashim, A. J. (2021). Development of integrated Islamic finance-based index of financial inclusion using zakat and cash waqf: A preliminary study in Malaysia . *The Journal of Muamalat and Islamic Finance Research*, 18(2), 73-95. <https://doi.org/10.33102/jmifr.v18i2.370>
- Ahmad, N., Hashim, N. H., & Abd Rahim, S. (2020). Is sukuk market efficient? Evidence from the Malaysian sukuk market. *The Journal of Muamalat and Islamic Finance Research*, 17(2), 32-43. <https://doi.org.10.33102/jmifr.v17i2.292>
- Alam, M. M., Akbar, C. S., Shahriar, S. M., & Elahi, M. M. (2017). The Islamic shariah principles for investment in stock market. *Qualitative Research in Financial Markets*, 9(2), 132-146. <https://doi.org/10.1108/QRFM-09-2016-0029>
- Amel-Zadeh, A., & Serafeim, G. (2018). Why and how investors use ESG information: Evidence from a global survey. *Financial Analysts Journal*, 74(3), 87-103. <https://doi.org/10.2469/faj.v74.n3.2>
- Askari, H., Iqbal, Z., Krichene, N., & Mirakhor, A. (2012). *Risk sharing in finance: The Islamic finance alternative*. John Wiley.
- Broadstock, D. C., Chan, K., Cheng, L. T., & Wang, X. (2021). The role of ESG performance during times of financial crisis: Evidence from COVID-19 in China. *Finance Research Letters*, 38, 101716. <https://doi.org/10.1016/j.frl.2020.10176>
- Dye, J., McKinnon, M., & Van der Byl, C. (2021). Green gaps: Firm ESG disclosure and Financial institutions' reporting requirements. *Journal of Sustainability Research*. <https://doi.org/10.20900/jsr20210006>
- El-Komi, M., & Croson, R. (2013). Experiments in Islamic microfinance. *Journal of Economic Behavior & Organization*, 95, 252-269. <https://doi.org/10.1016/j.jebo.2012.08.009>
- Emerson, S., Kennedy, R., O'Shea, L., & O'Brien, J. (2019). Trends and applications of machine learning in quantitative finance. *8th International Conference on Economics and Finance Research (ICEFR 2019)*.
- Harikumar, S., & Surya, P. V. (2015). K-medoid clustering for heterogeneous datasets. *Procedia Computer Science*, 70, 226-237. <https://doi.org/10.1016/j.procs.2015.10.077>
- Hassan, H. (2017). *Crowdfunding from an Islamic finance perspective*. ISRA - Thomson Reuters Islamic Commercial Law Report 2017.
- Kotsantonis, S., Pinney, C., & Serafeim, G. (2016). ESG integration in investment management: Myths and realities. *Journal of Applied Corporate Finance*, 28(2), 10-16.
- Lettau, M., & Madhavan, A. (2018). Exchange-traded funds 101 for economists. *Journal of Economic Perspectives*, 32(1), 135-154. DOI: 10.1257/jep.32.1.135
- Likas, A., Vlassis, N., & Verbeek, J. J. (2003). The global k-means clustering algorithm. *Pattern Recognition*, 36(2), 451-461. [https://doi.org/10.1016/S0031-3203\(02\)00060-2](https://doi.org/10.1016/S0031-3203(02)00060-2)
- Mawdudi, S. (2011). *First principles of Islamic economics*. The Islamic Foundation.

- Mohamed, H., & Ali, H. (2018). *Blockchain, Fintech, and Islamic finance: Building the future in the new Islamic digital economy*. Walter de Gruyter GmbH & Co KG.
- Moisseron, J. Y., Moschetto, B. L., & Teulon, F. (2015). Islamic finance: A review of the literature. *International Business & Economics Research Journal*, 14(5), 745-762. <https://doi.org/10.19030/iber.v14i5.9375>
- O'Leary, L., & Hauman, M. (2020). Regulatory implications of ESG investment. *Journal of Financial Transformation*, 163-171.
- S&P Dow Jones Indices. (2021, December 30). *S&P 500 Shariah*. <https://www.spglobal.com/spdji/en/indices/equity/sp-500-shariah-index/#overview>
- Schoon, N. (2008). Islamic finance – An overview. *European Business Organization Law Review*, 9(4), 621-635. doi:10.1017/S1566752908006216
- SESRIC. (2021). *OIC economic outlook 2021*. Organization of Islamic Cooperation.