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A Study on The Factors of Financial Freedom Influencing Digital Financial Usage: Empirical Evidence Through Data Mining Techniques

Dijital Finans Kullanımlarında Etkili Olan Finansal Serbestlik Faktörleri Üzerine Bir İnceleme: Veri Madenciliği Teknikleri ile Ampirik Kanıtlar

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ABSTRACT

The study examined the financial freedom factors that are effective in the use of digital finance. In order to conduct this examination, first of all, all countries in the world in the research sample were clustered according to their levels of digital finance use, and then the financial freedom factors that are effective in the use of digital finance were determined.

The reason for studying this topic is that it is thought that digitalization will positively affect the financial freedom, financial participation, financial development and economic growth of countries and that digitalization will be used as a tool in this regard. The importance of the impact of digital finance on financial participation and freedom emerges when financial services are offered equally to society without making any distinction between the poor and the rich.

One of the ways to achieve sustainable economic growth is to provide and strengthen economic freedom through digital finance. However, there are some restrictions and obstacles encountered on this path. Despite these problems, as a result of the analysis, it has been determined that countries with high digital finance usage are both more economically free and more financially developed.

JEL Codes: G17, G53

Keywords: Digitalization, Digital Finance, Financial Inclusion, Economic Freedom, Data Mining Technique

ÖZ

Yapılan çalışmada dijital finans kullanımında etkili olan finansal serbestlik faktörleri incelenmiştir. Bu incelemeyi yapabilmek için öncelikle araştırma örneklemindeki tüm dünya ülkeleri dijital finans kullanım düzeylerine göre kümelenmiş, ardından ise dijital finans kullanımında etkili olan finansal serbestlik faktörleri saptanmıştır.

Bu konunun çalışılma sebebi dijitalleşme ile ülkelerin finansal özgürlük, finansal katılım, finansal kalkınma ve ekonomik büyümelerinin pozitif yönde etkileneceği ve dijitalleşmenin bu konuda araç olarak kullanılacağı düşünülmektedir. Dijital finansın finansal katılıma ve özgürlüğe etkisinin önemi; finansal hizmetlerin fakir, zengin ayrımı yapılmaksızın topluma eşit olarak sunulduğunda ortaya çıkmaktadır.

Sürdürülebilir bir ekonomik büyümenin yollarından biri ekonomik özgürlüğü dijital finans yoluyla sağlamak ve güçlendirmekten geçmektedir. Ancak bu yolda karşılaşılan bazı kısıtlamalar ve engeller yer almaktadır. Bu problemlere rağmen analizler sonucunda dijital finans kullanımı yüksek olan ülkelerin hem ekonomik açıdan daha özgür hem de finansal açıdan daha gelişmiş durumda oldukları tespit edilmiştir.

JEL Kodları: G17, G53

Anahtar Kelimeler: Dijitalleşme, Dijital Finans, Finansal Katılım, Ekonomik Özgürlük, Veri Madenciliği Tekniği

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Introduction

In contemporary world, technological advancements have initiated the process of digitization in various fields, including finance. The digitization of financial products and services contributes to the continuous development of the finance sector and the emergence of new financial technologies. In this context, it is possible to say that concepts representing technological progress, such as blockchain, the Internet of Things, and artificial intelligence have assumed pioneering roles in the development of digital finance (DF) terms such as cryptocurrency and Fintech.

The almost entirely information-based nature of financial products and services underscores the necessity of digitization for the finance sector (Puschmann, 2017, pp. 63). The integration of information and communication technology (ICT) with the finance sector brings many advantages, including mitigating information asymmetry, minimizing transaction costs, and improving accessibility (Li et al., 2020, p. 317). The process of change experienced with the use of ICTs in the financial sector is expressed with concepts such as e-finance, FinTech and DF, which have similar meanings (Gomber et al., 2017, p. 537). E-finance is defined as instant access to financial services, financial products, and financial markets using ICTs to conduct real-time financial transactions (Allen et al., 2002, pp. 5-6). Fintech, on the other hand, refers to the provision of financial and banking services through modern technological innovations (Ozilli, 2018, pp. 331-332). DF is an alternative financial model developed to provide cost-effective, accessible, and easily adaptable financial services and products (Yang et al., 2023, p. 2). It encompasses commercial activities in the finance sector using technologies such as machine learning (ML), blockchain, and big data (Mu et al., 2023, p. 2; Shen & Huang, 2016, p. 221).

The emergence of digital payment technologies associated with the concept of DF enables the restructuring of financial systems involving the use of mobile banking, mobile financial applications for prepaid cards, and so forth, when combined with mobile phone technology (Aziz & Naima, 2021, p. 2). The ICTs providing access to the financial system, usability, and ease of use for financial information users constitute a driving force in the improvement of financial inclusion (FI) and the spread of the financial base (Sarma & Pais, 2011, p. 613). FI is seen as a potential transformative factor that can lead to poverty reduction and create a more financially inclusive society (Bruhn & Love, 2014, p. 1347; Sassi & Goaied, 2013, p. 252). Digital FI is a new area of financial development (FD) that eliminates geographical boundaries in traditional FI and strengthens small businesses with internet and big data technology to lower financing costs (Geng & He, 2021, p. 307). The measurement of digital FI at the country level is provided by the digital FI index, which consists of the availability of financial products, the availability of financial services, the normalization of financial services, and digitization (Geng & He, 2021, p. 309).

Digitization is considered a significant step not only for a country's financial freedom (FF), financial development (FD), and financial inclusion (FI) but also for its economic growth (EG) (Sara & Kayal, 2022, p. 1). Financial stability (FS), FD, and FF are crucial for sustainable global development. In this context, it is believed that sustainable global development can be achieved through DF and economic freedom (EF). EF is known to be a key factor in a country's EG, ensuring FS, and sustaining its overall economic performance.

Economic freedom refers to a situation where individual preferences are prioritized, trade can be conducted freely in markets, there is free access to markets, and there is the possibility of free competition in markets (Altınışık et al., 2011, p. 150). In addition to economic freedom, the concepts of financial stability, financial development, and financial freedom are also crucial for sustainable global development. Considering this importance, digital finance can be seen as an effective tool for sustainable global development.

The study examines the factors of FF influencing digital financial usage. To conduct this examination, all countries in the research sample were clustered based on their levels of DF usage, and then the factors of FF influencing DF usage were identified. The motivation for studying this topic is the belief that countries' FF, FI, financial development, and EG will be positively impacted by digitization, which will be utilized as a tool in this regard. The importance of the impact of DF on FI and freedom arises when financial services are equally provided to society without discrimination between the rich and the poor.

Literature Review

The relationship between DF and EF has been examined for all countries worldwide in the study. To conduct this examination, DF and EF were disaggregated into sub-indicators, and their connection was measured through these indicators.

The indicators used for measuring DF include data obtained from the World Bank and consist of 9 key indicators. These indicators are expressed as the number of: current accounts, accounts at financial institutions, credit card accounts, debit card accounts, credit or debit card accounts, saving at a financial institution, accumulating savings with a non-family member or a savings institution, borrowing from a formal financial institution, and borrowing from family or friends. All these indicators are determined by the World Bank and are represented for individuals aged 15 and above, denoting the level of maturity.

The literature review section of the study is divided into two groups, with the first group focusing on whether DF promotes FI.

Keskin (2025) examined neobanking and embedded finance systems, which are new products of financial technology, from a theoretical perspective. Information is provided on the introduction of the concepts of neobanking and embedded finance and how they are incorporated into digital financial systems. The aim of the study is to raise awareness about new financial products and to make assessments about the future of neobanking and embedded finance systems in Turkey.

Al-Smadi (2023) measured the relationship between DF and FI. The measurement was conducted in the North African and Middle Eastern countries. Totally, five control variables with a sample of 12 countries were utilized over the period 2004 - 2020. The findings asserted that DF usage promoted FI.

Güz and Poyraz (2023) explicated the DFI levels and developments of 75 countries over the period 2017 - 2021 in comparison with current data by introducing a Digital Financial Inclusion Index (DFII). High-income countries are at the top of the digital financial inclusivity index, whereas low-income countries are at the bottom.

Demirel et al. (2023) investigated the influence of digital payments on the accessibility and depth of financial institutions within the Turkish Banking Sector. The research encompasses the timeframe from 1990 to 2021, utilizing data sourced from the World Bank, IMF, and Interbank Card Center (BKM). The study showed that things like the number of credit cards, debit cards, ATMs, and POS devices all have a positive effect on the depth of financial institutions. It was decided that there should be more ATMs and POS devices to make it easier for people to get to banks and other financial institutions. As a result, it was noted that financial innovations in digital payments enhance the accessibility and depth of financial institutions.

Mahdzan et al. (2023) assessed the influence of digital financial service utilization on individuals' financial well-being. The sample consisted of economically disadvantaged individuals in Malaysia. We chose low-income people because they were more likely to be financially excluded and didn't have the knowledge or skills to manage their money. The results indicate that the utilization of DF diminishes the beneficial influence of financial literacy (FL) on financial well-being while simultaneously mitigating the detrimental effects of financial stress on financial well-being. This means that people with high FL are expected to have high levels of financial well-being, but using DF can change this. It was also noted that DF helps people deal with money problems.

Ekmen (2023) made an internet banking index that covers the years 2006 to 2016. The goal of this index is to see how digital banking affects FI. After 2008, the index rose quickly, which was due to the fact that more people around the world started using smartphones after the 2008 crisis.

Yue et al. (2022) elucidated the impact of DF on citizens. Numerous studies have indicated that DF enhances FI while simultaneously elevating individuals' borrowing risk. The results support this finding, showing that using DF makes more people participate in credit markets. This leads to more spending and a greater chance of getting into debt traps.

Xia et al. (2022) examined the stock prices of Chinese companies listed on the stock exchange and investigated the influence of DF on corporate resilience (CR) in response to the COVID-19 pandemic. The research indicated that enterprises situated in areas with elevated DF utilization encountered diminished losses and exhibited rapid recovery from the pandemic. It was determined that DF improves CR in conjunction with other analyses and findings.

Wang et al. (2020) examined the influence of DF on financial efficiency (FE). The research conducted in China revealed regional disparities in efficiency. The results show that there is a big difference in FE between eastern and non-eastern parts of China. The eastern part is much

more efficient than the other part, which is mostly due to development. The overall results showed that DF and FE were positively related. Nonetheless, it was determined that DF disadvantages underdeveloped regions.

Shofawati (2019) examined the function of DF in enhancing FI and SME development. This study was carried out employing qualitative research methodologies in Indonesia. The study found that digital access, which is a security risk for banks, is not a problem for SMEs. In fact, DF makes it easier for SMEs to get capital and loans.

Durai and Stella (2019) looked into how DF affects FI. They stressed how important DF is to people's daily lives. The study found that mobile banking is better when it has features like accessibility, convenience, good time management, the ability to use accounts at different banks, and low service fees. So, it was found that internet banking, mobile banking, mobile apps, credit cards, and debit cards all worked very well to improve FI.

Research studies on the relationship between DF and EF were discussed in the second part of the literature review.

Kaya and Özkan (2024) perfomed a causality test for FD and EF utilizing the annual data of 27 OECD-member countries over the period 1995-2018. The analysis detected a unilateral causality from FD to EF, meaning that countries with higher levels of FD were economically freer, and FD enhanced EF.

Chinoda and Kapingura (2024) conducted a research regarding Sub-Saharan African countries, explicating the effect of governance and institutions on DF participation and EG over the period 2014 – 2020. The results revealed the existence of positive impacts of governance and institutional quality on EG and DF participation.

Meng and Xiao (2023), who examined the DF and happiness relationship in China, found negative results, because of enhanced spending behavior and high borrowing levels. Nonetheless, such findings were determined to differ by age, debt levels, and trust levels.

Manasseh et al. (2023) studied the impacts of FI and DF on EG employing a panel ARDL method utilizing annual data of sixteen COMESA-member countries over the period 1997-2018. The findings asserted that DF and FI stimulate EG. Besides, a bilateral causality was detected between DF, FI, and EG.

Tariq et al. (2023) intended to measure the impact of DF on EG. With a sample of 77 countries between 2011-2021 the analysis employing the GMM suggested a shift to a cashless economic system by promoting DF in developing countries.

Luo et al. (2022) analyzed the impact of DF on financial sustainability performing a data envelopment analysis for. 31 provinces of China. The results revealed that technological advancements promote FE, and DF improvements stimulated regional FE. Expanding the scope and depth of DF will maximize FE and promote the development of the financial sector.

Li and Liu (2022) examined the impact of DF on corporate independent innovation and commercial credit in Shanghai and Shenzhen A-share listed companies from 2012 to 2020. The results show that DF supports corporate independent innovation, and commercial credit and government subsidies assume an intermediary role in the relationship between DF and corporate independent innovation.

Saraf & Kayal (2022) studied the impact of digitization on economic and FF. Initially, the relationship between FI and FF and ways to improve FF were explored. It was observed that the use of digital financial services through ICTs leads to FF and financial development.

Bunje et al. (2022) examined the impacts of FD on trade in the context of the digital economy (DE). The study covered 47 African countries from 1990 to 2019. Panel data analysis with dynamic GMM models was used. The results indicate that FD and the DE have a direct impact on trade. The DE is also one of the most important factors that affect FD and trade in Africa in the short and long term. Consequently, it is underscored that policies advocating for the DE in Africa should be promoted.

Rekha et al. (2021) examined the correlations among digital financial inclusion, economic factors, financial development, and growth. They utilized panel data analysis incorporating cointegration and vector error correction models to examine 22 developing nations. As ICTs have improved, long-term digital FI has been shown to have a positive effect on EF and financial development. This effect is expected to bolster sustainable EG. It was also shown that FI has a positive effect on EG over time, and that growth leads to more FI.

Hussain et al. (2021) investigated the correlation among FL, EF, quality management, and FI. They employed panel data analysis. The results indicate that FL and public

quality have a positive impact on FI. It has also been shown that the quality of government is a link between FL and FI. When government quality gets better, EF gets stronger, and when both are doing well, FI goes up.

Keskin Köylü (2018) assessed the impact of information technology utilization on corporate productivity within the framework of conducted studies. It was stated that businesses need to continuously improve their performance in order to be sustainable and thus gain a competitive advantage. The study also emphasized that the best way to improve performance and convert it into activity is through the use of information technology.

The second section includes studies related to the association between DF and EF. Although it emerges that DF enhances EF, there are underlying reasons for this inference. The presence of ICTs not only drives financial systems towards digitalization but also enhances EG. Access to financial services and the availability of services are facilitated through digital FI. On the other hand, EF impacts financial development, development, and growth. With digitalization, it is believed that countries' FF, FI, financial development, and EG will be positively affected, and digitalization will be used as a tool in this regard. The significance of the impact of DF on FI and freedom arises when financial services are provided to society equally without distinction between rich and poor.

In addition, studies on the dependent and independent variables of the subject are included in the literature section; however, literature on the method is not included. Because the main purpose of the subject is to measure the effect of digital finance use on financial freedom.

Method: C-Means Clustering Analysis

Clustering analysis is a technique based on unsupervised learning logic, aiming to group decision units showing a high level of similarity. In the literature, there are various clustering techniques, including metric, grid, density, or model-based methods. C-Means technique is a metric-based clustering technique. The method is based on the idea of initially dividing decision units into a predetermined number of clusters. The application steps of the method are as follows (Hamerly & Elkan, 2003):

- k random cluster centers are selected from the X dataset,

- The distance between data points and cluster center values is calculated,

- Data points are assigned to the clusters to which the centers with the smallest distance belong,

- Final cluster centers are optimized.

- If there are decision units that change clusters, reassignment is made, and final clusters are determined.

A crucial aspect of the C-Means technique is determining the number of clusters k. In this stage, GAP, Elbow, or Silhouette techniques are used (Sinaga & Yang, 2020). In this study, the Silhouette index is utilized. The Silhouette index, also known as silhouette statistic, was developed by Rousseeuw in 1987. The formula for the coefficient is as follows;

$$s(i) = \frac{b(i) - a(i)}{max\{a(i), b(i)\}}$$

In the equation, a(i) denotes the average distance from the data point in index i to all other data points in the same cluster, while b(i) denotes the minimum distance from the same data point to all data points in other clusters. The index varies between 0 and 1, with values closer to 1 indicating successful clustering.

Fuzzy C-Means is an exploratory technique among unsupervised learning techniques. That is, the method groups decision units without any information about the outcome of the application. Therefore, it differs from the hypothesis testing logic used in classical statistical techniques.

Random Forest Regression Analysis

Random Forest regression (RFR) analysis is one of the supervised ML techniques. The method was initially developed by Leo Breiman, inspired by Amit and Geman's work in 1997. The RF method is based on bagging technique, where multiple decision trees are run for regression or classification algorithms. Then, for regression, the average of decision tree outputs is taken, while for classification, a voting system is used to create the final model (Segal, 2004).

The most significant advantage of using this method is its resilience against overfitting, which is one of the most critical problems in ML techniques (Tatachar, 2021). Particularly, the situation where the output is memorized based on the input for limited data sets and variable sets can be cited as an example. RF fundamentally has two parameters: the number of randomly selected predictors

at each node (m) and the number of trees in the forest (j). These parameters are usually optimized to generate the final model. Subsequently, the importance levels of variables in the model can be determined based on the change in Mean Squared Error (MSE) when each variable is removed from the prediction model (Han et al., 2016).

Purpose and Scope of the Study

The aim of the study is to examine the factors of FF that are effective in DF usage. In this context, firstly, clustering of countries according to their levels of DF usage is aimed, and then, the factors of FF that are effective in DF usage are intended to be determined.

The study covers the years 2011, 2014, 2017, and 2021. These years were selected because the data set is only available for these years. Accordingly, 138 countries were evaluated in 2011, 136 in 2014, 138 in 2017, and 118 in 2021.

The reason for choosing this method is to cluster countries according to their level of financial freedom. For this purpose, clustering algorithms from unsupervised learning techniques should be applied. At the same time, the Fuzzy C-Means technique was used because fuzzy logic is the approach that best suits human thought and decision-making structures.

Results

Clustering of Countries According to Their Digital Finance Usage

In the first stage of the study, fuzzy C-Means method was applied with 9 variables related to DF usage, and clustering analysis was performed to divide the countries into 4 different clusters. At this stage, different numbers of clusters were tried for determination, and it was considered appropriate to divide the countries into 4 clusters based on their international literature compatibility and the most suitable Silhouette score (Pham et al., 2005). The naming of the clusters was done based on the average values of the cluster centroids.

Table 1.

Fuzzy C-Means Clustering

Clusters	N	R^2	AIC	BIC	Silhouette
4	530	0.689	1617.770	1788.690	0.860

The Silhouette index value, which measures the success of clustering analysis, was found to be 0.86, and the R2 value was 68.9%. Therefore, it can be stated that the clustering was successful. Accordingly, the results obtained are as shown in the table below.

Table 2.

Cluster Information

Cluster	1	2	3	4
Size	156	125	134	115
Explained proportion within-cluster heterogeneity	0.338	0.260	0.187	0.215
Within sum of squares	519.561	399.631	287.753	330.828
Silhouette score	0.269	0.106	0.269	0.416
Account	0.441	-0.702	-1.012	1.289
Financial institution account	0.485	-0.666	-0.917	1.302
Owns a credit card	0.058	-0.505	-0.850	1.421
Owns a debit card	0.347	-0.585	-0.731	1.544
Owns a debit or credit card	0.307	-0.579	-0.781	1.478
Saved at a financial institution	-0.355	-0.658	-0.831	1.615
Saved using a savings club or a person outside the family	0.109	0.253	-0.505	-0.347
Borrowed from a formal financial institution	0.160	-0.513	-0.920	1.514
Borrowed from family or friends	-0.222	-0.517	-0.242	-1.062
Average	**0.15**	**-0.50**	**-0.75**	**0.97**

Note. The Total Sum of Squares of the 4 cluster model is 4947.44

The central values resulting from the clustering analysis were used to obtain the mean values, and cluster names were created accordingly. Thus, Cluster 1 was labeled as high, Cluster 2 as low, Cluster 3 as very low, and Cluster 4 as very high. The frequency table of countries over the years is as follows:

Table 3.

Income Distribution of Clusters

Year	Very Low	Low	High	Very High
2011	67	16	35	20
2014	33	34	42	27
2017	18	46	41	33
2021	16	29	38	35

As seen in the table, the distributions of countries vary for each year. However, it is observed that DF usage increases over the years, and countries generally advance in this regard. This situation can be attributed to the facilitation of access to DF with the advancement of technology.

The Determination of Financial Freedom Factors Influencing Digital Finance Usage

In the second phase of the study, the cluster values obtained in the first step were considered as the dependent variable, and FF variables were taken as independent variables, followed by the application of the Random Forest classification algorithm. The reason for using the RFR technique is its recommendation as the most resistant algorithm against overfitting among algorithms. In practice, the optimal number of trees was found to be 95. The results obtained are as follows:

Table 4.

Evaluation Metrics

	1	2	3	4	Average/ Total
Support	28	18	14	26	86
Accuracy	0.919	0.814	0.837	0.988	0.890
Precision (Positive Predictive Value)	0.862	0.556	0.500	0.963	0.769
Recall (True Positive Rate)	0.893	0.556	0.429	1.000	0.779
False Positive Rate	0.069	0.118	0.083	0.017	0.072
False Discovery Rate	0.138	0.444	0.500	0.037	0.280
F1 Score	0.877	0.556	0.462	0.981	0.774
Matthews Correlation Coefficient	0.817	0.438	0.368	0.973	0.649
Area Under Curve (AUC)	0.941	0.863	0.882	0.997	0.921
Negative Predictive Value	0.947	0.882	0.892	1.000	0.930
True Negative Rate	0.931	0.882	0.917	0.983	0.928
False Negative Rate	0.107	0.444	0.571	0.000	0.281
False Omission Rate	0.053	0.118	0.108	0.000	0.070
Threat Score	2.273	0.417	0.300	13.000	3.997
Statistical Parity	0.337	0.209	0.140	0.314	1.000

Note. All metrics are calculated for every class against all other classes.

The table demonstrates that the applied classification algorithm has been successful. Accordingly, the validation accuracy value is 71%, the test accuracy value is 77.9%, and the Out of Bag (OOB) score is determined to be 90.3%. This indicates that the algorithm has been effectively trained (Strobl et al., 2007). Additionally, the study aims to rank the factors influencing classification as a result of the RFR application. The list of variables used in the study is provided in the attachment to avoid disrupting the text flow and occupying too much space. The results obtained are as follows:

Table 5.

Feature Importance

	Mean decrease in accuracy	Total increase in node purity
d20	-6.028×10^{-4}	0.036
d9	0.012	0.035
d19	0.002	0.031
d8	6.269×10^{-4}	0.022
d1	0.003	0.021
d2	0.013	0.019
d29	-7.250×10^{-4}	0.019
d11	0.005	0.019
d7	0.018	0.015
d13	-0.003	0.015
d30	0.004	0.013
d6	0.008	0.012
d24	0.009	0.011
d10	0.002	0.011
d25	-9.490×10^{-4}	0.008
d3	-5.436×10^{-4}	0.004
d12	0.016	0.004
d22	0.005	0.003
d14	8.839×10^{-4}	0.002
d16	-4.284×10^{-4}	0.002
d5	0.002	0.002
d15	0.002	0.001
d17	0.005	8.585×10^{-4}
d4	2.997×10^{-4}	1.933×10^{-4}
d23	-2.858×10^{-4}	-5.432×10^{-4}
d18	0.001	-7.891×10^{-4}
d28	0.008	-0.001
d21	4.179×10^{-4}	-0.001
d27	2.792×10^{-4}	-0.003
d26	0.005	-0.003

Upon examining the importance levels of variables, it is found that the most important factors in DF usage are 4B Regulatory trade barriers, Military interference, and Costs of importing and exporting. Conversely, the least important variables are Controls of the movement of capital and people, Credit market regulation, and Black market exchange rates.

Conclusion

Along with globalization, the competition phenomenon has become highly influential in financial markets. Both at the micro and macro levels, businesses must keep pace with evolving technologies to create awareness. Competing, even excelling, in competition requires undergoing transformation and development. Digitalization, once present but now dominant worldwide, especially during the pandemic, has become an indispensable concept. With the impact of digitalization, terms such as e-finance, Fintech, and DF have emerged in the financial sector, enabling people to handle their tasks where they are, saving time. These concepts are also crucial for countries' FFs, development, and progress. In

other words, sustainable growth requires these concepts to work together in an integrated manner. This study explores the relationship between DF, which is crucial for sustainable growth, and EF.

The aim of the study is to examine the FF factors that are effective in DF usage. Accordingly, countries were first divided into 4 different clusters using 9 indicators showing DF usage. Then, the aim was to examine the FF factors that are effective in countries' DF usage based on these cluster divisions. As a result of the applications, 12 countries were classified as very low, 18 as low, 29 as high, and 27 as very high. Upon comparing the resulting clusters by income groups, a strong relationship between income status and DF usage was found with a coefficient of 0.75. Therefore, it can be stated that countries with a high level of income are also at a high level in terms of DF usage.

In the second part of the study, the aim was to examine the FF factors effective in the clusters created in the first stage. Accordingly, RFR analysis was applied, and the result showed that 89% of the countries were correctly classified. This indicates the reliability of the application in the first stage. In examining the factors effective in classification, the mean decrease in accuracy technique was used. It was found that the most important factors in the clustering based on DF usage were 4B Regulatory Trade Barriers, Military interference, and costs of importing and exporting, while the rest were the least important variables.

One of the most crucial factors in DF is likely to be the trade regulatory barriers. This is because when trading internationally, tariff-like barriers, quantity restrictions, taxes, quotas, embargoes, and sanctions can be imposed. In this case, both the EF of countries is limited and they may face problems in conducting trade through DF.

The second important factor in DF is military interventions. In this regard, situations such as war between countries, hostilities, military coups, etc., are cited as examples. Military interventions both restrict EF and hinder trade through DF.

Another important factor is the costs of exports and imports. This issue is directly related to the pricing policies implemented by all countries. The aim of countries in trading exports and imports with each other is to mitigate the trade deficit. Encouraging exports is crucial to achieve this goal.

Based on all these findings, one of the means of achieving sustainable EG is to ensure and strengthen EF through DF. However, there are some constraints and barriers encountered along this path. Despite these problems, it was found through analysis that countries with high DF usage are both economically freer and more financially advanced.

It is recommended that the study be developed to serve as a reference for future studies. Furthermore, it is crucial that financial freedom, economic development, and advancement are compatible and integrated with each other to ensure sustainable growth. Therefore, in the global era, the relationship between digital finance and economic freedom is important in terms of seeing the compatibility between these concepts.

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Extended Abstract

Amaç ve Motivasyon: Yapılan çalışmada ise dijital finans kullanımında etkili olan finansal serbestlik faktörleri incelenmiştir. Bu incelemeyi yapabilmek için öncelikle araştırma örneklemindeki tüm dünya ülkeleri dijital finans kullanım düzeylerine göre kümelenmiş, ardından ise dijital finans kullanımında etkili olan finansal serbestlik faktörleri saptanmıştır.

Araştırma Stratejisi ve Yöntemi: Çalışmada dijital finans kullanımlarında etkili olan finansal serbestlik faktörlerinin incelenmesi amaçlanmıştır. Buna göre öncelikle ülkeler dijital finans kullanımını gösteren 9 gösterge kullanılarak 4 farklı kümeye ayrılmıştır. Daha sonra bu küme ayırımlarına göre ülkelerin dijital finans kullanımlarında etkili olan finansal serbestlik faktörlerinin incelenmesi amaçlanmıştır. Yapılan uygulamalar neticesinde ülkelerden 12'si çok düşük, 18'i düşük, 29'u yüksek ve 27'si çok yüksek sınıfta yer almıştır. Çalışmanın ikinci kısmında ise ilk aşamada oluşturulan kümelerde etkili olan finansal serbestlik faktörlerinin incelenmesi amaçlanmıştır. Bu doğrultuda Rassal Orman regresyon analizi uygulanmış olup ülkelerin %89'unun doğru sınıflandırıldığı sonucu elde edilmiştir. Bu durum ilk aşamada yapılan uygulamanın güvenirliğini göstermektedir. Sınıflandırmada etkili olan faktörlerin incelenmesinde Rassal Orman Regreson analizi kullanılmıştır.

Bulgular ve Tartışma: Çalışmanın ilk aşamasında bulanık K-Means yöntemiyle dijital finans kullanımlarına yönelik 9 değişken ile kümeleme analizi uygulanarak ülkeler 4 farklı kümeye ayrılmıştır. Bu aşamada küme sayısının belirlenmesinde farklı sayıda küme değerleri denenmiş ve uluslararası literatüre uygun olması ve en uygun Silhouette skoru neticesinde 4 kümeye ayrılması uygun görülmüştür. Kümelerin isimlendirilmesi ise küme merkezi değerlerinin ortalamasına göre yapılmıştır.

Çalışmanın ikinci aşamasında ise ilk adımda elde edilen küme değerleri bağımlı; finansal serbestlik değişkenleri bağımsız değişken olarak alınmış ve Rassal Orman sınıflandırma algoritması uygulanmıştır. Burada Rassal Orman tekniğinin kullanılmasının sebebi algoritmalar içerisinde ezberlemeye karşı en dirençli algoritma olarak önerilmesi nedeniyledir. Uygulamada optimum ağaç sayısı 95 bulunmuştur.

Değişkenlerin önem düzeyleri incelendiği durumda ise dijital finans kullanımlarında en önemli faktörün 4B düzenleyici ticari engeller, askeri müdahale ve ithalat-ihracat maliyetleri; en az önemli değişkenlerin ise karaborsa döviz kurları, sermaye ve insan hareketinin kontrolleri ve kredi piyasası düzenlemesi olduğu bulgularına ulaşılmıştır.

Sonuç ve Öneriler: Çalışmada dijital finans kullanımlarında etkili olan finansal serbestlik faktörlerinin incelenmesi amaçlanmıştır. Buna göre öncelikle ülkeler dijital finans kullanımını gösteren 9 gösterge kullanılarak 4 farklı kümeye ayrılmıştır. Daha sonra bu küme ayırımlarına göre ülkelerin dijital finans kullanımlarında etkili olan finansal serbestlik faktörlerinin incelenmesi amaçlanmıştır. Yapılan uygulamalar neticesinde ülkelerden 12'si çok düşük, 18'i düşük, 29'u yüksek ve 27'si çok yüksek sınıfta yer almıştır. Oluşan kümeler ile gelir grupları kıyaslandığı durumda korelasyon analizi sonucu anlamlı ve katsayı 0.75 çıkmış olup, gelir durumu ile dijital finans kullanımı arasında güçlü bir ilişki tespit edilmiştir. Bu durumda gelire göre yüksek gelişmiş düzeyde olan ülkelerin dijital finans kullanımları açısından da yüksek düzeyde oldukları ifade edilebilir.

Dijital finans konusunda en önemli faktörlerden birinin ticareti düzenleyen engeller olması muhtemeldir. Çünkü uluslararası boyutta ticaret yaparken tarife benzeri engeller, miktar kısıtlamaları, vergi, kotalar, ambargolar ve yaptırımlar konulabilir. Bu durumda ülkelerin hem ekonomik özgürlükleri sınırlandırılır hem de ticareti dijital finans yoluyla yaparken problemler yaşamalarına yol açmaktadır.

Dijital finans konusunda ikinci önemli faktörün askeri müdahaleler olduğu tespit edilmiştir. Bu konuda ise ülkelerin birbirleri arasındaki savaş durumları, husumetler, askeri darbe vb. durumlar örnek olarak gösterilmektedir. Askeri müdahaleler hem ekonomik özgürlüğü kısıtlamakta hem de dijital finans yoluyla ticarete ket vurmaktadır.

Diğer bir önemli faktör ise ihracat ve ithalat maliyetleridir. Bu konu tüm ülkelerin uygulamış olduğu fiyat politikalarıyla doğrudan ilişkilidir. Ülkelerin birbirleriyle ihracat ve ithalat yaparken hedefledikleri politika dış ticaret açığını düşürmektir. Bu hedefi yerine getirmek için ihracatı teşvik etmeleri son derece önem arz etmektedir.

Tüm bu bulgulardan hareketle; sürdürülebilir bir ekonomik büyümenin yollarından biri ekonomik özgürlüğü dijital finans yoluyla sağlamak ve güçlendirmekten geçmektedir. Ancak bu yolda karşılaşılan bazı kısıtlamalar ve engeller yer almaktadır. Bu problemlere rağmen analizler sonucunda dijital finans kullanımı yüksek olan ülkelerin hem ekonomik açıdan daha özgür hem de finansal açıdan daha gelişmiş durumda oldukları tespit edilmiştir.