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Development of Digital Economy, Human Development Solution in Iran

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ABSTRACT

Recent information and communication technology developments have led to digitizing society and countries. The increase in productivity and efficiency of these societies, together with digitization, has sparked the expectation that developing the digital economy in Iran will lead to human development. In this research, the digital economy index of 31 provinces of Iran over the period from 2013 to 2023 was first ranked using Principal Component Analysis (PCA). Then, they were placed in three clusters: Very Suitable, Suitable and Very Unsuitable. In the next step, Copula's approach was applied to investigate the role of the digital economy in human development. The results showed a correlation between the human development of Iran's provinces and the digital economy development of Iran's provinces. Based on this, the development of digital economy in the provinces of Iran can be a way for human development.

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1. Introduction

There have been significant advances in information and communication technology in recent years. These developments have caused many industries and equipment to undergo significant changes and evolve (Aceto, Persico, & Pescapé, 2019; ElMaraghy et al., 2021). So far, three industrial revolutions have affected the development process of the world. The first industrial revolution happened at the end of the 18th century with the construction of machines and the establishment of the first factories (Har et al., 2022). The second industrial revolution happened with the division of labor and the use of electricity in production (Mohajan, 2019). The third industrial revolution also occurred between 1970 and 2000 under the information and internet revolution (Taalbi, 2019). In today's era, the fourth revolution based on the Internet of Things, artificial intelligence, and cyber-physical systems is occurring. The fourth industrial revolution has made significant progress in recent years and faster than the previous three industrial revolutions (Hassoun et al., 2023). Technological advancements have increased productivity in production, distribution, and consumption processes, and producers and consumers have access to more quantity and quality services and goods at a lower cost (Koh, Orzes, & Jia, 2019). Recent information and communication technology advances have affected both the public and private sectors and made them more productive in their activities. These developments in the public sector have led to the formation of a concept called electronic government. Electronic government includes a set of public sector activities that have been facilitated with the help of technology and have reduced public sector costs (Dhaoui, 2022; Mensah, 2019). In the private sector, technological advances have led to the formation of various concepts, primarily e-commerce, which is the most critical achievement of information and communication technology for businesses. E-commerce refers to management processes and buying and selling in business based on information and communication technology. E-commerce has improved the efficiency of production, supply and consumption of goods and services. The development of e-commerce followed by the digitization of the economy will increase and improve the quality and quantity of goods and services available to the people of the society (Borenstein & Saloner, 2001; Jain, Malviya, & Arya, 2021; Pantelimon, Georgescu, & Posedaru, 2020). Finally, all these changes and the influence of technology in society are included in the concept of digital economy. The digital economy is all economic and social activities based on information and communication technology. In other words, the digital economy is the stage in which economic and social activities take a new form based on technology (Barefoot et al., 2018; Li et al., 2020). Organization for Economic Co-operation and Development (OECD) defines the digital economy as all economic activity reliant on or enhanced by digital inputs, including digital technologies, infrastructure, services, and data (Bukht & Heeks, 2017; Williams, 2021). The achievements of the world in the digitalization process will not be limited to these things. The world's primary and most important achievement of digitization is the integrated development of societies and countries. Today, the world's countries are changing and evolving with digitization; looking at developed countries, it is clear that these countries have developed in the field of digital economy. In the country, the digital economy creates conditions with high productivity. For this reason, supporting the digital economy can be the basis of the country's development and progress. The digitization of countries' economies will be the foundation of the globalization process. In other words, the fields of globalization will increase with the development of the digital economy (Skare & Soriano, 2021; Voronkova et al., 2023; Zhao et al., 2023). Studies show that the development of the digital economy in developing countries could be at a higher level. In developing countries, the infrastructure and policies of the digital economy have yet to be given much attention (Bahadirovich, 2023; Kolesnikov et al., 2020). Iran is a developing country located in the Middle East (Nazaritehrani & Mashali, 2020). Official reports show that the digital economy's contribution to Iran's gross domestic product (GDP) in 2020 was 6.5%. At the same time, this rate was 2.2% in 2013. Based on this, the share of the digital economy in Iran's economy has increased by 4.3% in the last seven years (Alfoul, 2022; Yalcintas & Alizadeh, 2020). The World Bank has announced that the average digital economy share in the world's GDP is more than 15% (Mallaboyev, 2023; Shevchenko et al., 2023). Although the share of the digital economy in Iran's GDP reached 6.5% in 2020, it is still 8.5% different from the global average, which can indicate the lack of development of the digital economy in Iran.

The purpose of developing and applying the digital economy is the development and progress of societies (Limna, Kraiwanit, & Siripipatthanakul, 2023). Iran has 31 provinces, each with special economic conditions, and each is at a level of development. By examining the provinces of Iran, it is clear that some of these provinces are less developed than others. Iran's policies have generally been such that the central and non-border provinces have developed more than the border provinces (Azadi, Delangizan, & Falahati, 2021; Kazemi et al., 2015; Omrani, Alizadeh, & Amini, 2020; Tondro et al., 2022). Also, the lack of attention of policymakers and planners to economic capacities and ways of economic and social development has caused many of these provinces not to be included in the development process. In many provinces of Iran, the lack of development has been a significant reason for the decreased of the quality of life and economic and social problems in these regions (Mosadeghrad et al., 2019; Yazdanpanah, Moradi, & Asgar Khani, 2023). The underdevelopment of these provinces has caused the increase in social crimes and poverty in these areas compared to other provinces (Deyhoul, Ahmadi, & Mirfardi, 2019). Based on this, all the factors and conditions to realize development in these deprived provinces of Iran must be investigated and studied. As mentioned, the digital economy provides conditions for developing the country and societies. Therefore, in this research the aim will be to investigate the role of the growth and development of the digital economy in the development of the provinces of Iran from 2013 to 2023 (Mosadeghrad et al., 2019; Zhang et al., 2021).

This research introduces several innovative aspects. Firstly, it applies the Digital Economy Index at the provincial level in Iran, using Principal Component Analysis (PCA) to rank 31 provinces and understand regional disparities. Secondly, it utilizes the Copula model to analyze the dependency between the Human Development Index (HDI) and the digital economy index, capturing complex, nonlinear relationships. Thirdly, it integrates advanced statistical methods with actionable policy recommendations, demonstrating how scientific findings can inform development policies. Fourthly, it focuses on regional analysis over a long-term period (2013-2023), providing robust insights for policymakers. Finally, the study addresses local challenges with practical solutions tailored to Iran's context.

2. Literature Review

In this research, the role of the digital economy in the development of Iranian provinces has been investigated. The digital economy index (DEI) has been used to check the performance of the digital economy of the Iranian provinces. Also, the human development index has been used to check the development of Iran's provinces. The Human Development Index (HDI) comprises three other indices: Life expectancy, Education, and Gross National Income (GNI) (Lind, 2019). In light of this, the theoretical foundations of the digital economy index and the impact of the digital economy on the development of societies and countries have been examined. Economic and social development of a society is a process containing a wide variety of factors. In other words, for a country to develop it must evolve in an integrated manner in economic and social components. The digital economy's role in the provinces' development can be examined by the effects of the digital economy on Human Development Index components (Laitsou & Xenakis, 2023; Yazdanpanah, Moradi, & Asgar Khani, 2023).

2.1. Human Development Index (HDI)

The digital economy creates conditions in the country where many services and goods rely on information and communication technology. In other words, the development of a digital economy in a country causes the penetration of technology in all parts of society (Irtyshcheva et al., 2021). One of the most essential components of society is education, which is considered the factor of human development. In an economy where a significant part is digital economy, digitalization in education is also increasing. The digitalization of education has the ability to create efficient educational methods, which leads to an increase in educational productivity. Based on this, the development of the digital economy will provide the foundation to transform the education system into a modern one, and then the human capital will be developed. With the improvement of human capital, more than ever before, skilled labor will be accessible and society will develop (Abduraxmanova, 2022; Akhmedov, 2023; Bygstad et al., 2022; Muralidharan, Shanmugan, & Klochkov, 2022; Sitepu et al., 2022). The digital economy has had a significant impact on improving life expectancy. Health sector performance greatly influences life expectancy; Advances in technology in recent years have created new treatment methods and intelligent medical equipment (Jiang, Chang, & Shahzad, 2022; Lyu et al., 2022; You et al., 2021). The digitization of societies improves the performance of governments in the field of providing welfare for society. In other words, the digitization of the economy in a society becomes a factor for improving the government's performance and planning. With the correct planning of the government, the efficiency of welfare programs will increase (Brynjolfsson et al., 2018; Febiri & Hub, 2021; Greve, 2019). The digital economy has caused the creation of e-commerce; E-commerce is a factor for easy access to goods and services. With more straightforward and cheaper access to goods and services than in the past, it will be possible to increase the quality of life and life expectancy (Darley, 2003; Le Thanh et al., 2022; Lee & Kim, 2019). Furthermore, the development of the digital economy has led to the creation of new jobs. New jobs have decreased the unemployment rate and thereby improved the quality of life, increasing life expectancy (Kamberidou, 2020; Lee & Clarke, 2019; Zhang, 2023). The main effect of the digital economy is the increase in Gross National Income. In general, the digital economy has caused productivity in the production of services and goods (Jiang & Murmann, 2022; Rehman & Nunziante, 2023); this increase in productivity is possible by reducing the cost of producers and the cost of access for consumers (Natalya et al., 2020). Generally, the countries where the digital economy has formed a more significant part of the Gross National Income are more developed. In other words, the digital economy will increase the Gross National Income, which will increase the quality of life and human development in these societies (Azamat et al., 2023; Faridah Pardi, 2021). The increase in Gross National Income is not achieved only by improving the performance of the public sector; the main factor of Gross National Income is the penetration of the digital economy in the private sector. The private sector is always looking for more profit, and since technology reduces costs and creates modern methods, the private sector will make the most of information and communication technology to make more profit. With increasing productivity and earning more private sector profit, Gross National Income will also increase (Borg et al., 2020; Di Giulio & Vecchi, 2023; Makhmudova Dilbar, 2021). Additionally, studies have been conducted on the impact of the digital economy on human development. Pylypenko & Shvets (2024) have found that digitalization enhances human capital by necessitating new skills and competencies, leading to a more knowledgeable workforce. Additionally, these researchers have emphasized that there is a significant correlation between the digital economy index and the development of human resources. Bakumenko and Minina (2020) have demonstrated that there is a correlation between social welfare and the digital economy index.

2.2. Digital Economy Index (DEI)

The research by Kim (2006), Stavytskyy, Kharlamova, and Stoica (2019), and Wang and Shi (2021) indicates that the infrastructure and performance of society's access to information and communication technologies can reflect the performance of the digital economy. Ovcharov and Terekhov (2023) have introduced household access to commonly used information and communication technology equipment as a metric for studying the digital economy's infrastructure. Prasetyani et al. (2024) have identified internet speed, the number of internet users, and the number of mobile phone users as key indicators of the digital economy. Mao (2023) has also identified the condition and status of fixed-line telephones as a factor in the digital economy. Therefore, in this study, the number of landline users, number of mobile phone users, number of internet users, and internet bandwidth have been examined as key indicators of the digital economy across the provinces of Iran.

3. Methods

In this research, the digital economy index of Iran's provinces has been ranked using principal component analysis. Then, using the Copula method, the correlation between the human development index and the digital economy index has been investigated. In this regard, the data of the Ministry of Communications and Information Technology of Iran have been used to rank the digital economy index of Iran's provinces. Additionally, data from the Global Data Lab have been used for the human development index of Iran's provinces. According to available data, the years examined in this research span from 2013 to 2023.

3.1. Principal Component Analysis (PCA)

In principal components analysis, the primary variables in the interrelated multi-state space are first converted into independent components. Each new component is considered a linear combination of the main variables. The main components are obtained through the eigenvalues of the covariance matrix or the correlation matrix of the main variables (Abdi & Williams, 2010). In the initial analysis of the main components, the input variables should be standardized. This standardization should have a mean of zero and a standard deviation of one and is achieved through this relationship:

$$Z_{ij} = \frac{(x_{ij} - \bar{x}_j)}{s_j} \tag{1}$$

$$for\ i = 1,2, \dots, n\ and\ j = 1,2, \dots, q$$

In the next step, the correlation matrix for primary variables is calculated, which is possible with relation 2. In this regard, the amount of each element of this matrix aij will show the correlation between variables i and j (Forkman, Josse, & Piepho, 2019).

$$R = \frac{1}{\pi} \acute{Z}Z \tag{2}$$

KMO should be calculated in the next step. The value of KMO will be in the range of zero to one. If the output of relation 3 is more than 0.5, the data will be suitable for the analysis of the main components of the study. However, if the output is less than 0.5, the data will not be efficient for this analysis (Ben Salem & Ben Abdelaziz, 2021; Greenacre et al., 2022).

$$KMO = \frac{\sum\sum r_{ij}^2}{\sum\sum r_{ij}^2 + \sum\sum a_{ij}^2} \tag{3}$$

Afterward, it is necessary to calculate the eigenvalues of λ and eigenvectors from the correlation matrix. The eigenvalue is a proportion of the total variance of the variables by which the components are determined. The eigenvectors obtained for each eigenvalue will be the coefficients of the primary variables in the component formation (Abdi & Williams, 2010).

$$det(R - \lambda I) = 0 \tag{4}$$

Equation 5 is used to calculate the variance of each of the main components.

$$det(R - \lambda I) = V_h \tag{5}$$

After this criterion, it will be desirable to extract the number of factors. Scree test criteria, eigenvalue, and variance percentage are considered the main parameters for extracting the number of factors. In the next step, the appropriate rotation should be determined on the matrix of coefficients of the studied components. In other words, at this stage, the variables with high factor load in the main components have been extracted and entered into the modeling as necessary variables. In the final stage, creating p primary variable xp is necessary to create a maximum of p independent components in the form of pcp. The following relation can be used to specify the principal component. In relation 6, pc specifies the desired component, w is the coefficient of primary variables, and x specifies primary variables (Kherif & Latypova, 2020; Ringnér, 2008).

$$PC_p = w_{p1}x_1 + w_{p2}x_2 + \cdots + w_{pp}x_p \tag{6}$$

3.2. Copula

Copula approach is a multivariate cumulative distribution function whose marginal distributions are uniformly distributed in the interval [0,1]. The application of copula functions allows the combination of any form of marginal cumulative probability functions; because the marginal distributions for building a multivariate model can be chosen independently. On the basis of this, it will not be necessary for the marginal function to follow a special distribution like the bivariate distribution functions. It should be noted that using copula leads to the description of changes in the degree of correlation of variables in different parts of the joint probability distribution (Fattahi & Kian poor, 2020; Patton, 2012).

3.2.1. Sklar's Theorem

If it is assumed that $F_{x,y}$ is a joint distribution function with the margins of F_x and F_y, then there will be a copula function C for each x, y in R.

$$F_{x,y}\,(x\,,y) = C\,(F_x\,(x), F_y\,(y)) \tag{7}$$

In this way, the copula function allows the model of the marginal distribution and dependence structure for a multivariate validation variable.

Moreover, copula functions provide the possibility to model the dependence between variables in the values of Karanjin or tail dependence (Trivedi & Zimmer, 2007).

3.2.2. Correlation Coefficients

One of the features of copula is that this class of functions considers the correlation between variables. In other words, in this situation, there will be no need for variable independence, and the correlation structure between variables will always exist. In copula approach, the correlation coefficient must be specific; because there is a parameter in the calculation of copula that shows the degree of dependence without scale (Jong-Min, 2020). Correlation coefficients are generally divided into Kendall's Tau and Spearman's Rho. Kendall's Tau coefficient measures and checks the degree of dependency between two variables. The coefficient will equal 1 when the match between two variables is perfect. On the contrary, if there is no match between two variables, the coefficient will be equal to -1. The critical point is that two variables are considered independent if the coefficient equals zero. Spearman's Rho coefficient is considered non-parametric, indicating the dependency between the variables. Spearman's Rho coefficient is calculated similarly to Kendall's Tau coefficient in a set of obtained data. This coefficient will be used in the conditions of lack of data (Ji, 2023; Safari-Katesari, Samadi, & Zaroudi, 2020).

3.2.3. Types of Copula

Copula types can be divided into parametric and non-parametric types. The parametric copula is usually used in research. One of the factors of less use of the non-parametric copula is related to the limitation in finding results with input data with the help of parameter estimation; parameters that indicate the degree of dependence of variables (Trivedi & Zimmer, 2007; Yan, 2023). Among the most well-known and main Copula functions, some examples are as follows.

• Archimedean Copula

Archimedean Copula is one of the copula types with a simple structure but a significant analytical feature.

$$C\ (u_1, u_2) = \varphi^{[-1]}\ [\varphi(u_1) + \varphi(u_2)] \tag{8}$$

The value of φ is considered a copula generator in continuous, non-negative, and convex conditions (Fattahi & Kian poor, 2020).

• Normal Copula

Normal Copula is also one of the most well-known types of Copula.

$$C^{Ga}\ (u_1, u_2;\ p)\ =\ \Psi_p\ (\Psi^{-1}(u_1), \Psi^{-1}(u_2)) \tag{9}$$

Ψp is a bivariate standard normal distribution function with correlation coefficient p ϵ (0,1) (Ji, 2023).

• Clayton Copula

Clayton Copula is a type of Archimedean copula. It has an asymmetric distribution in which the dependence on the negative sequence is more than the dependence on the positive sequence (Liu et al., 2020).

$$C_c\ (u_1, u_2)\ =\ max\ [(u_1^{-\theta} + u_2^{-\theta}\ - 1{,}0] \tag{10}$$

Naturally, the generating function of this type of copula should be noted as follows:

$$\varphi(t)\ =\ \theta^{-1}(t^{-\theta} - 1), where\ \theta\ \epsilon\ [-1, +\infty) \tag{11}$$

• Frank Copula

Frank Copula is also considered a symmetrical Archimedean copula (De Baets & De Meyer, 2013).

$$C_F = (u_1, u_2) =\ -\frac{1}{\theta} In\ (1 + \frac{(e^{-\theta u_1} - 1)(e^{-\theta u_2} - 1)}{e^{-\theta} - 1}) \tag{12}$$

The generating function of Frank Copula is as follows:

$$\varphi(t) =\ -\mathrm{In}\left(\frac{e^{-\theta t} - 1}{e^{-\theta} - 1}\right)\ , \theta \neq 1 \tag{13}$$

• Gumbel Copula

Gumbel Copula is also one of the Archimedean copulas, which is asymmetric and shows more dependence in the positive than in the negative sequence (Fischer et al., 2009).

$$C_g(u_1, u_2) = exp(-[(-In(u_1))^{\theta} + (-In(u_2))^{\theta}]^{\theta-1}) \tag{14}$$

The generating function of Gumbel Copula is as follows:

$$\varphi(t) = (-In(t))^{\theta}, \theta \geq 1 \tag{15}$$

• Elliptical Copula

The Elliptical Copula's feature is the correlation between marginal distributions at different levels (Fischer et al., 2009).

$$p(x, y) = sin\frac{\pi}{2}\mathcal{T} \tag{16}$$

• Extreme Value Copula

In Extreme Value copula, all values $(u_1, \ldots, u_d) \in [0,1]^d$ must be satisfied (Safari-Katesari, Samadi, & Zaroudi, 2020).

$$C_F(U_1^{\frac{1}{n}}, \ldots, U_d^{\frac{1}{n}})^n \Rightarrow C(u_1, \ldots, u_d) \quad (n \rightarrow \propto) \tag{17}$$

4. Analysis of Results

4.1. Ranking the Digital Economy Index of Iranian Provinces

As the number of features or dimensions in a dataset increases, the amount of data required to obtain a statistically significant result increases exponentially. This can lead to overfitting issues, increased computation time, and reduced model accuracy. Also, the number of dimensions increases exponentially, resulting in the increase of the number of possible combinations of features, which increases the computational difficulties of obtaining a representative sample of the data, and the difficulty of performing tasks such as clustering or classification. Principal component analysis, or PCA, is a statistical method enabling the simultaneous analysis of information content in large data tables using a smaller set of “summary indices” that can be easily visualized and analyzed. In this research, principal component analysis has been done with Eviews and XLSTAT software to provide additional background and discuss clustering.

Table 1. Eigenvalues

Components	Initial eigenvalues		
	Value of each component	**Variance (percentage)**	**Cumulative (percentage)**
Number of landline users	2.938	73.47	73.47
Number of mobile phone users	0.999	24.98	98.45
Number of internet users	0.0465	1.16	99.61
Internet bandwidth	0.015	0.39	100

Source: Research finding

As clearly seen and shown in the table, the factor of the number of landline users with a special value of 2.938 alone covers 73.47% of the variance and has the most impact among the four effective factors.

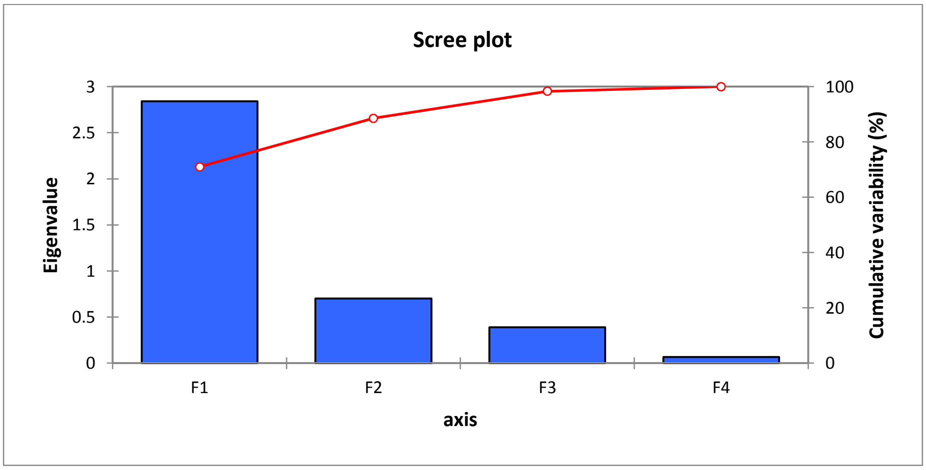

Fig 1. Scree plot of factors with eigenvalues

Source: Research finding

In addition, in the scree plot diagram of the factors, a factor with the largest eigenvalues has been selected and from then on the curve decreases sharply and the eigen variance becomes less than the common variance. The KMO[1] index, an index of sampling adequacy, examines the smallness of partial correlation between variables and thus determines whether the variance of the research variables is influenced by the common variance of some hidden and fundamental factors or not. The index value close to 0.70 demonstrates that the desired data (sample size) are suitable for factor analysis.

Table 2. Values of KMO Index

Components	Values of KMO
Number of landline users	0.650
Number of mobile phone users	0.637
Number of internet users	0.881
Internet bandwidth	0.650
KMO	0.698

Source: Research finding

Furthermore, the biplots method method indicates that in the ranking section of the number of landline users, it has the highest ranking in the sample units and in the species section based on the similarity matrix.

1. Kaiser-Meyer-Olkin Measure of sampling adequancy

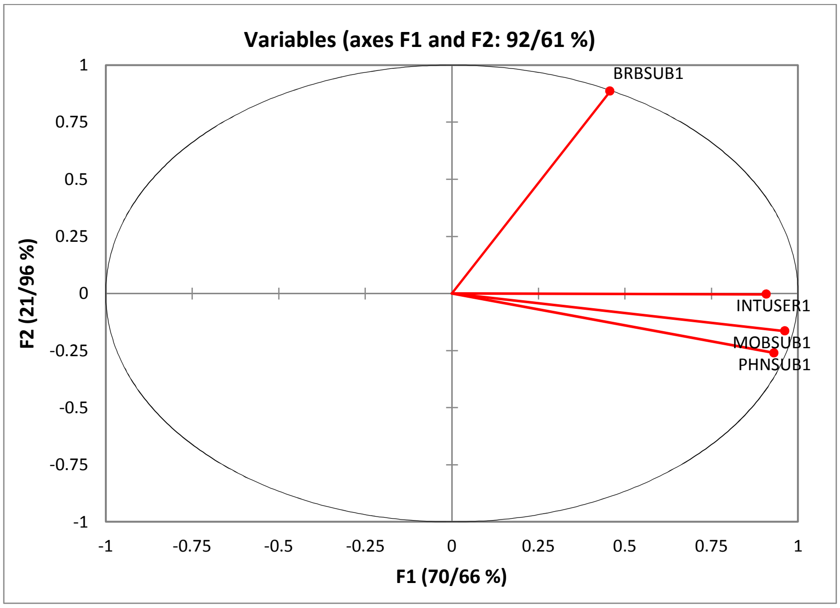

Fig 2. Biplots diagram

Source: Research finding

Ranking based on principal component analysis method

After the principal component analysis, the model process ranks the indicators using SPSS software.

Table 3. Ranking of Iran's provinces based on digital economy index

Province	Index	Rank	Province	Index	Rank
Tehran	31	1	Golestan	15.91	17
Isfahan	30	2	Kurdestan	13.27	18
Razavi Khorasan	29	3	Lorestan	12.82	19
Fars	28	4	Hormozgan	12.82	19
East Azarbaijan	26.9	5	Qazvin	11.18	20
Mazandaran	25.82	6	Sistan and Baluchistan	10.64	21
Khuzestan	25.27	7	Bushehr	9.27	22
Gilan	23.55	8	Ardabil	8.73	23
West Azarbaijan	22.5	9	Zanjan	7.27	24
Kerman	21.55	10	Semnan	6.18	25

Province	Index	Rank	Province	Index	Rank
Yazd	19.45	11	Chahar Mahaal and Bakhtiari	4.91	26
Kermanshah	19.09	12	South Khorasan	4.09	27
Alborz	18.91	13	North Khorasan	3	28
Qom	18.09	14	Ilam	1.64	29
Markazi	18	15	Kohkiluyeh and Buyer Ahmad	1.36	30
Hamedan	16.55	16			

Source: Research finding

The results from the table indicate that Tehran and Isfahan provinces have ranked first and second, respectively, with composite indices of 31 and 30. Ilam and Kohkiluyeh and Buyer Ahmad provinces, on the other hand, have assigned the lowest ranks for the composite index, with 1.64 and 1.36, respectively.

4.1.1. Cluster analysis

Cluster analysis is a technique used to group similar observations into a number of clusters based on the observed values of several variables for each individual. Additionally, cluster analysis is a statistical method for data processing. It works by organising items into groups or clusters according to their relativeness. Similar to diminishing space analysis, cluster analysis pertains to data matrices in which variables have not been pre-divided into subsets against prediction. The aim of cluster analysis is to identify similar groups of subjects, where “similarity” between any pair of objects is measured as an overall assessment across the set of features. In this research, XLSTAT software has been used for the cluster analysis of the index, which is made according to the number of nodes and the central distance and the center of the class and the weighting of this index:

Table 4. Clustering of provinces

Digital economy indicators in three clusters		
Group 1 (Very Suitable)	**Group 2 (Suitable)**	**Group 3 (Very Unsuitable)**
East Azarbaijan	Ardabil	Alborz
West Azarbaijan	Ilam	Qom
Isfahan	Bushehr	Kermanshah
Tehran	Chahar Mahaal and Bakhtiari	Golestan
Razavi Khorasan	South Khorasan	Markazi
Khuzestan	North Khorasan	Hamedan
Fars	Zanjan	Yazd
Kerman	Semnan	
Gilan	Sistan and Baluchistan	
Mazandaran	Qazvin	
	Kurdestan	
	Kohkiluyeh and Buyer Ahmad	
	Lorestan	
	Hormozgan	

Source: Research finding

The status of the digital economy index of Iran's provinces was classified according to the cluster analysis method into three groups: very suitable, suitable, and very unsuitable. In addition, the final output is classified into three homogeneous clusters using XLSTAT software in the form of dendrogram.

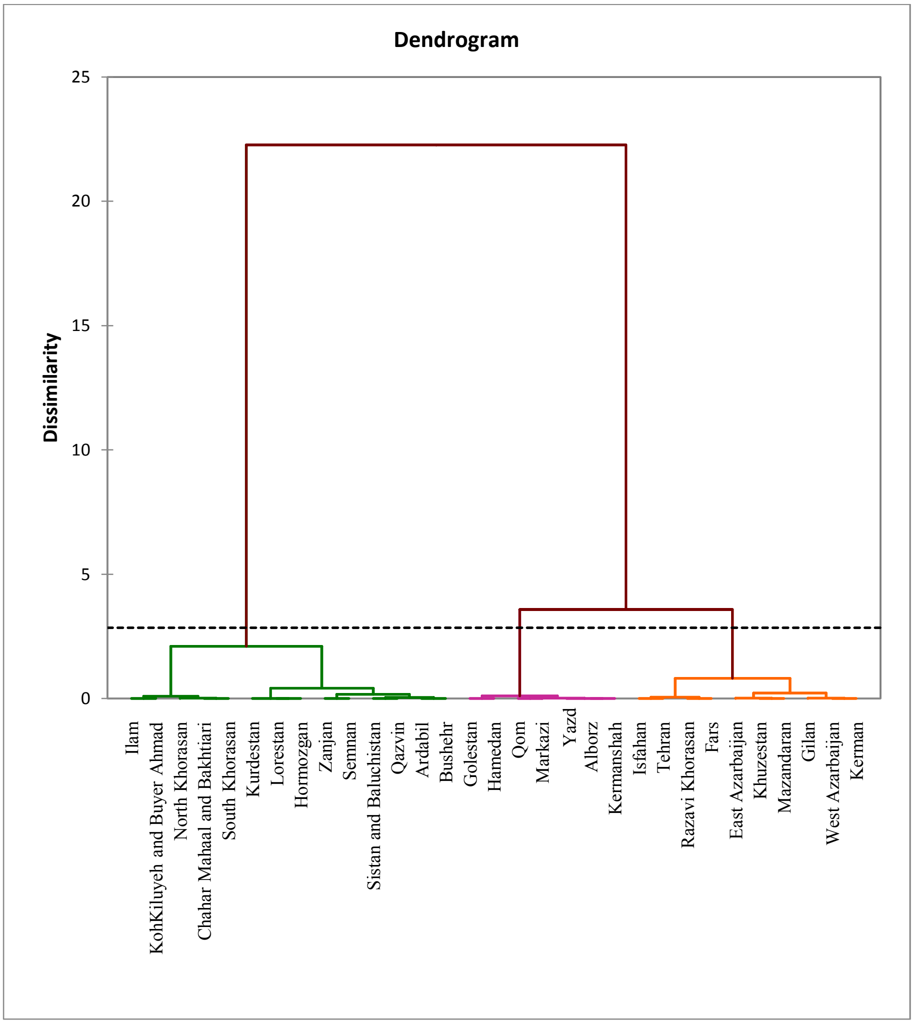

Fig 3. Dendrogram

Source: Research finding

4.2. The correlation between the Human Development Index and the Digital Economy Index of Iranian Provinces

The graphs shown below show the marginal and normal distributions of human development and digital economy variables. In this section, local optimization and Markov chain Monte Carlo simulation are used in the

Bayesian framework to derive the parameter values of Copula families by contrasting them with the available data. If Bayesian analysis is performed with Markov chain Monte Carlo simulation, the posterior distribution of the pair's parameters can be used to estimate the uncertainty of each data pair. In the Bayesian framework, the Markov chain Monte Carlo provides a robust estimate of the global optimum and approximates the posterior distribution of the pair families, which can be used to construct a prediction uncertainty bound for the pairs. The local optimization methods are highly susceptible to be trapped in local optima. Tawn posterior distributions and Clayton posterior distributions are obtained by Markov chain Monte Carlo simulation in the Bayesian framework, where the resulting line represents the Copula value obtained by the local approach and the obtained points derived from the chain Monte Carlo are Markov and show maximum likelihood. It should also be noted that the normality of each variable is displayed.

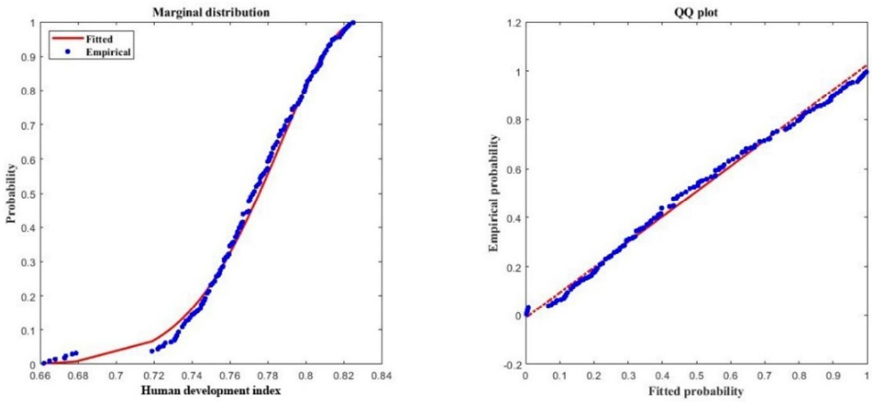

Fig 4. Marginal distribution and normal distribution of human development variable

Source: Research finding

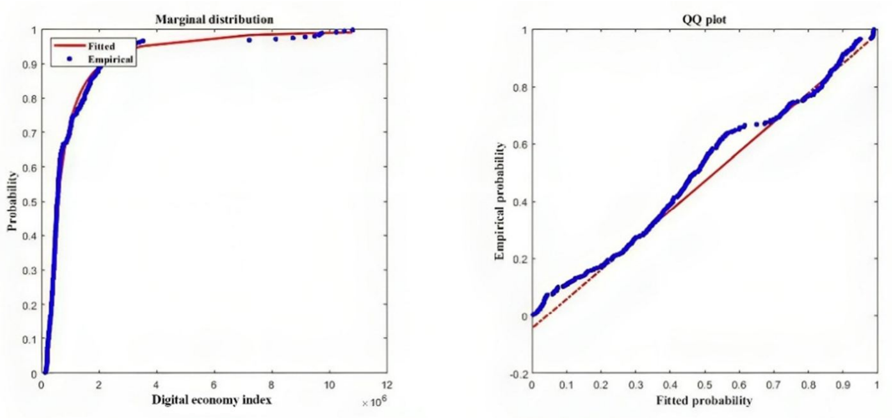

Fig 5. Marginal distribution and normal distribution of digital economy variable
Source: Research finding

In the following, the structure of dependence between human development and the digital economy is obtained from the observed data and it shows the description of the structure as asymmetric dependence.

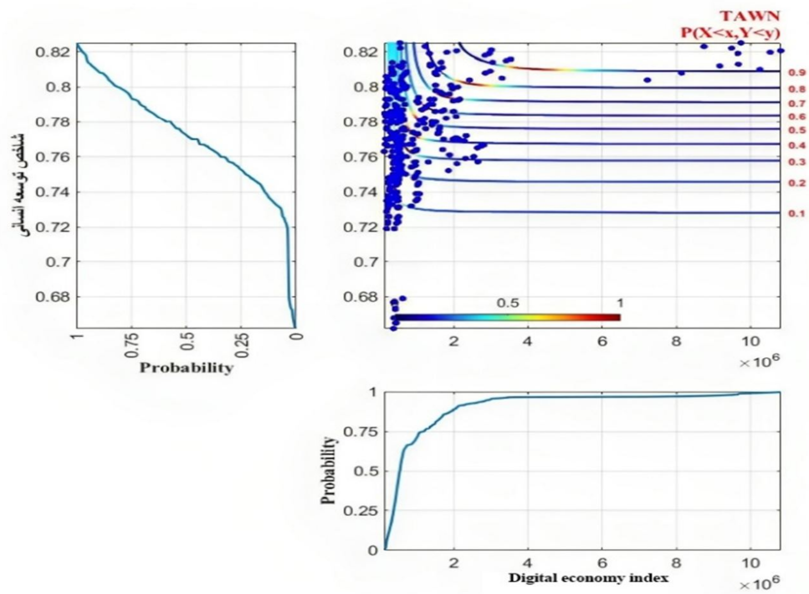

Fig 6. Dependency structure of human development variables and digital economy
Source: Research finding

As mentioned above, tail dependence is a measure to check the dependence of variables in their limit states. The motivation behind using Copula functions, which show tail dependence, is that one of the objectives of this research is to investigate the relationship between human development and the digital economy. Thus, to investigate the limit states of these two variables, Copula functions showing the tail dependence and, as a result, the related effects should be sought. The tail dependence between human development and the digital economy is now calculated for the types of Copula functions that show the tail dependences. Results of this calculation are given in the table. For each pair of variables, the appropriate Copula function is selected according to the maximum likelihood criterion, Akaike's criterion, Bayesian, Least squares error, and Nash equilibrium.

Table 5. Joint probability distribution of Copula functions between human development and digital economy

Rank	AIC	BIC	Max-Likelihood
1	Tawn	Tawn	Tawn
2	Marshal-Olkin	Marshal-Olkin	Marshal-Olkin
3	Gumbel	Gumbel	Roch-Alegre
4	Galambos	Galambos	Gumbel
5	Roch-Alegre	Roch-Alegre	BB5
6	BB5	BB5	BB1
7	BB1	BB1	Galambos
8	Burr	Burr	Burr
9	Joe	Joe	Joe
10	t	t	t
11	Fischer-Hinzmann	Fischer-Hinzmann	Fischer-Hinzmann
12	Gaussian	Gaussian	Gaussian
13	Cuadras-Auge	Cuadras-Auge	Cuadras-Auge
14	Plackett	Plackett	Plackett
15	Frank	Frank	Frank
16	Nelsen	Nelsen	Nelsen
17	FGM	FGM	FGM
18	Fischer-Kock	Linear-Spearman	Fischer-Kock
19	Linear-Spearman	Shih-Louis	Linear-Spearman
20	Shih-Louis	Fischer-Kock	Shih-Louis

Rank	AIC	BIC	Max-Likelihood
21	AMH	AMH	AMH
22	Clayton	Clayton	Clayton
23	Raftery	Raftery	Raftery
24	Cubic	Cubic	Cubic
25	Independence	Independence	Independence

Source: Research finding

Table 6. Estimated parameters of Copula functions between human development and digital economy

Copula Name	RMSE	NSE
Gaussian	0.2737	0.9969
t	0.2678	0.9971
Clayton	0.3813	0.9941
Frank	0.2866	0.9966
Gumbel	0.2439	0.9976
Independence	0.7784	0.9753
AMH	0.3408	0.9953
Joe	0.2645	0.9971
FGM	0.3095	0.9961
Plackett	0.2818	0.9968
Cuadras-Auge	0.2762	0.9969
Raftery	0.4229	0.9927
Shih-Louis	0.3116	0.9960
Linear-Spearman	0.3116	0.9960
Cubic	0.7518	0.9769
Burr	0.2567	0.9973
Nelsen	0.2866	0.9966
Galambos	0.2444	0.9976
Marshal-Olkin	0.1845	0.9986
Fischer-Hinzmann	0.2686	0.9971
Roch-Alegre	0.2437	0.9976
Fischer-Kock	0.3095	0.9961
BB1	0.2439	0.9976
BB5	0.2439	0.9976
Tawn	0.1816	0.9987

Source: Research finding

Findings show that the data have a normal distribution according to Q-Q plot. Additionally, in the Bayesian framework, local optimization and Markov chain Monte Carlo simulation were used to derive the parameter values of Copula families. The appropriate Copula function was simulated for each pair of variables, according to the maximum likelihood criterion, Akaik criterion, Bayesian, least squares error, and Nash equilibrium. on the basis of this, Tawn Copula indicated the relationship between digital economy and human development. It is known that Copula Tawn obtains the asymmetric dependence structure of probabilistic isolines. Furthermore, the Nash equilibrium with the approximate value of 0.9987 for Copula Tawn also shows the excellent fit of Copula Tawn with the data, which also has the minimum root mean square error. Finally, the results of estimating the Copula function between digital economy efficiency and human development were expressed in paired Copula models. This section's results also show an asymmetric dependence between the digital economy and human development. Hence, Copula Tawn has the best explanation according to the values of the maximum likelihood, Akaike's information criterion, the minimum mean squared error, and Nash equilibrium. This result indicates that the digital economy and human development have a sequence dependence of components with positive value. Accordingly, with the increase of digitalization in the country, we will face an increase in human development. Also, in the dependence structure between the digital economy and human development, the fundamental uncertainty precision in the measurement is evident in the dependence structure. The range of uncertainty is shown with isolines paired with red, and the observed data is presented with blue dots. Also, the range of uncertainty is only due to the effects of parameter uncertainty obtained in Bayesian analysis. Hence, it is proved that the scenario of Copula Tawn can be applied to each sector to model the dependence of digital economy and human development.

5. Conclusion and Policy Recommendations

The research results show a correlation between Iran's provinces' digital economy index and the human development index. In provinces with high development in the state of digital economy, human development is at higher levels, and the development of digital economy can be considered as one of the factors of human development in Iran’s provinces. The human development index shows the quality of life in society. Based on this, the development of digital economy can improve the quality of life of people in society. Some provinces of Iran are in an unfavorable situation regarding human development. The research results prove that the lack of development of the digital economy in these provinces is considered one of the factors of lack of human development. It is anticipated that with the digitization of the economy of the provinces of Iran, human development will increase and the residents of Iran’s undeveloped provinces will benefit from a better quality of life. Since the increase and improvement of the performance of the digital economy index increases the human development index, it is evident that the development of the digital economy in each province of Iran improves education, life expectancy and gross national income in that province. In order to develop the digital economy in Iran, it is necessary to change the policy and planning methods in the field of digital economy. The public sector policies should be in a way that causes the development of the digital economy in provinces with a low human development index. The impossibility of mid-term and long-term planning in the digital economy field is one of Iran's main problems. Political uncertainty and differences between experts and policymakers have caused the development of the digital economy to be absent from many medium and long-term plans. Therefore, it is necessary to propose policy recommendations in the field of digital economy.

- **Investment in Digital Infrastructure**: The government should prioritize investments in digital infrastructure, particularly in underdeveloped provinces. This includes improving internet connectivity, enhancing telecommunications networks, and ensuring access to digital tools.

- **Facilitating Investment Conditions**: Establish favorable conditions for domestic and foreign investment in the digital economy sector. This includes offering tax exemptions and legal support for investors in less developed provinces to reduce investment risks.
- **Digital Literacy Programs**: Implement comprehensive digital literacy programs aimed at equipping residents, especially youth and women, with necessary skills to participate in the digital economy. This could involve partnerships with educational institutions and NGOs to provide training and resources.
- **Public-Private Partnerships**: Encourage collaboration between government and private sector to leverage resources and expertise for the development of digital infrastructure and services.
- **Developing International Relations**: Pay more attention to globalization and establish constructive economic, political, and social relations with other countries to reduce sanctions and facilitate the entry of new technologies into the country.
- **Promotion of E-Government Services**: Expand e-government services to make public services more accessible to citizens in remote areas. This will not only improve efficiency but also enhance transparency and accountability within government operations.
- **Strengthening Cybersecurity Measures**: As digital economies grow, it's crucial to invest in cybersecurity measures to protect individuals and businesses from cyber threats, thereby building trust in digital platforms.
- **Encouraging Research and Development**: Support RD initiatives focused on creating innovative solutions that can enhance the digital economy within provinces. This can be achieved through funding research projects at universities and research institutions.

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The authors declare no conflict of interest

References

Abdi, H., & Williams, L. J. (2010). Principal component analysis. *WIREs Computational Statistics*, *2*(4), 433-459. https://doi.org/10.1002/ wics.101

Abduraxmanova, S. A. (2022). Individualization of professional education process on the basis of digital technologies. *World Bulletin of Social Sciences*, *8*, 65-67.

Aceto, G., Persico, V., & Pescapé, A. (2019). A survey on information and communication technologies for industry 4.0: State-of-the-art, taxonomies, perspectives, and challenges. *IEEE Communications Surveys & Tutorials*, *21*(4), 3467-3501.

Akhmedov, B. A. (2023). Improvement of the digital economy and its significance in higher education in tashkent region. *Uzbek Scholar Journal*, *12*, 18-21.

Alfoul, M. N. A. (2022). *Effects of ICT Investment and Usage on Economic Growth in MENA Countries: Does Governance Matter* Swinburne University of Technology Hawthorn, VIC, Australia].

Azadi, A., Delangizan, S., & Falahati, A. (2021). The role of governments in Iran regional development (case study: tenth government). *Iranian Economic Review*, *25*(1), 1-20.

Azamat, O., Sherzod, S., Dilshod, S., Gulyar, K., Gulnur, A., Zarifa, K., & Sarvar, T. (2023). The Role of Digital Technology in the Future of Insurance and Economic Development. *Journal of Law and Sustainable Development*, *11*(5), e1081. https://doi.org/10.55908/sdgs.v11i5.1081

Bahadirovich, A. F. (2023). Condition for the formation of a digital economy in the republic of Uzbekistan, *Gospodarka i Innowacje*., 365-370.

Bakumenko, L. P., & Minina, E. A. (2020). International index of digital economy and society (I-DESI): trends in the development of digital technologies. *Statistics and economics*, 17(2), 40-54. https://doi.org/10.21686/2500-3925-2020-2-40-54

Barefoot, K., Curtis, D., Jolliff, W., Nicholson, J. R., & Omohundro, R. (2018). Defining and measuring the digital economy. *US Department of Commerce Bureau of Economic Analysis, Washington, DC*, *15*, 210.

Ben Salem, K., & Ben Abdelaziz, A. (2021). Principal Component Analysis (PCA). *La Tunisie medicale*, *99*(4), 383-389.

Borenstein, S., & Saloner, G. (2001). Economics and electronic commerce. *Journal of Economic Perspectives*, *15*(1), 3-12.

Borg, M., Wernberg, J., Olsson, T., Franke, U., & Andersson, M. (2020). *Illuminating a Blind Spot in Digitalization - Software Development in Sweden's Private and Public Sector* Proceedings of the IEEE/ACM 42nd International Conference on Software Engineering Workshops, Seoul, Republic of Korea. https://doi.org/10.1145/3387940.3392213

Brynjolfsson, E., Diewert, W. E., Eggers, F., Fox, K. J., & Gannamaneni, A. (2018). The digital economy, GDP and consumer welfare: Theory and evidence. ESCoE Conference on Economic Measurement, Bank of England.

Bukht, R., & Heeks, R. (2017). Defining, conceptualising and measuring the digital economy. *Development Informatics working paper*(68).

Bygstad, B., Øvrelid, E., Ludvigsen, S., & Dæhlen, M. (2022). From dual digitalization to digital learning space: Exploring the digital transformation of higher education. *Computers & Education*, *182*, 104463.

Darley, W. K. (2003). Public policy challenges and implications of the Internet and the emerging e-commerce for sub-Saharan Africa: A business perspective. *Information Technology for Development*, *10*(1), 1-12. https://doi.org/10.1002/itdj.1590100102

De Baets, B., & De Meyer, H. (2013). On a conjecture about the Frank copula family. *Fuzzy Sets and Systems*, *228*, 15-28. https://doi.org/10.1016/j.fss.2012.07.007

Deyhoul, M., Ahmadi, S., & Mirfardi, A. (2019). Development and Crime in Iran. *Quarterly of Social Studies and Research in Iran*, *8*(3), 581-608.

Dhaoui, I. (2022). E-government for sustainable development: Evidence from MENA countries. *Journal of the Knowledge Economy*, *13*(3), 2070-2099.

Di Giulio, M., & Vecchi, G. (2023). Implementing digitalization in the public sector. Technologies, agency, and governance. *Public Policy and Administration*, *38*(2), 133-158. https://doi.org/10.1177/09520767211023283

ElMaraghy, H., Monostori, L., Schuh, G., & ElMaraghy, W. (2021). Evolution and future of manufacturing systems. *CIRP Annals*, *70*(2), 635-658.

Faridah Pardi, Z. S., Mohd Azlan Abd Majid, Sutina Junos, Noor Azillah Mohamad Ali. (2021). Digital Economy and Sustainable Development Path in Selected Asian Countries. *Global Business and Management Research*, *13*(4), 167-180.

Fattahi, S., & Kian poor, S. (2020). The Dependence of Returns in Stock Exchange Returns and Gold Markets with Spread of Covid-19 Virus in Iran: The Copula Functions Approach. *Journal of Economics and Modelling*, *11*(2), 181-221. (In Persian) https://doi.org/10.29252/jem.2021.185233.1493

Febiri, F., & Hub, M. (2021). Digitalization of Global Economy: A Qualitative Study Exploring Key Indicators use to measure digital progress in the Public sector. SHS Web of Conferences. Volume 92 (2021),

Fischer, M., Köck, C., Schlüter, S., & Weigert, F. (2009). An empirical analysis of multivariate copula models. *Quantitative Finance*, *9*(7), 839-854. https://doi.org/10.1080/14697680802595650

Forkman, J., Josse, J., & Piepho, H.-P. (2019). Hypothesis Tests for Principal Component Analysis When Variables are Standardized. *Journal of Agricultural, Biological and Environmental Statistics*, *24*(2), 289-308. https://doi.org/10.1007/s13253-019-00355-5

Greenacre, M., Groenen, P. J. F., Hastie, T., D'Enza, A. I., Markos, A., & Tuzhilina, E. (2022). Principal component analysis. *Nature Reviews Methods Primers*, *2*(1), 100. https://doi.org/10.1038/s43586-022-00184-w

Greve, B. (2019). The digital economy and the future of European welfare states. *International Social Security Review*, *72*(3), 79-94.

Har, L. L., Rashid, U. K., Te Chuan, L., Sen, S. C., & Xia, L. Y. (2022). Revolution of retail industry: from perspective of retail 1.0 to 4.0. *Procedia Computer Science*, *200*, 1615-1625.

Hassoun, A., Aït-Kaddour, A., Abu-Mahfouz, A. M., Rathod, N. B., Bader, F., Barba, F. J., Biancolillo, A., Cropotova, J., Galanakis, C. M., & Jambrak, A. R. (2023). The fourth industrial revolution in the food industry—Part I: Industry 4.0 technologies. *Critical Reviews in Food Science and Nutrition*, *63*(23), 6547-6563.

Irtyshcheva, I., Stehnei, M., Popadynet, N., Bogatyrev, K., Boiko, Y., Kramarenko, I., Senkevich, O., Hryshyna, N., Kozak, I., & Ishchenko, O. (2021). The effect of digital technology development on economic growth.

Jain, V., Malviya, B., & Arya, S. (2021). An overview of electronic commerce (e-Commerce). *Journal of Contemporary Issues in Business and Government*, *27*(3), 665-670.

Ji, X. (2023). Multivariate Extreme Wind Loads: Copula-Based Analysis. *Journal of Engineering Mechanics*, *149*(1), 04022082. https://doi.org/10.1061/(ASCE)EM.1943-7889.0002174

Jiang, C., Chang, H., & Shahzad, I. (2022). Digital economy and health: does green technology matter in BRICS economies? *Frontiers in Public Health*, *9*, 827915.

Jiang, H., & Murmann, J. P. (2022). The Rise of China's Digital Economy: An Overview. *Management and Organization Review*, *18*(4), 790-802.
https://doi.org/10.1017/mor.2022.32

Jong-Min, K. (2020). A Review of Copula Methods for Measuring Uncertainty in Finance and Economics. *Quantitative Bio-Science*, *39*(2), 81-90.

Kamberidou, I. (2020). "Distinguished" women entrepreneurs in the digital economy and the multitasking whirlpool. *Journal of Innovation and Entrepreneurship*, *9*(1), 3.
https://doi.org/10.1186/s13731-020-0114-y

Kazemi, A., Rezapoor, A., Faradonbeh, S. B., Nakhaei, M., & Ghazanfari, S. (2015). Study the development level of provinces in Iran: a focus on health indicators. *Journal of Health Administration (JHA)*, *18*(59). (In Persian)

Kherif, F., & Latypova, A. (2020). Chapter 12 - Principal component analysis. In A. Mechelli & S. Vieira (Eds.), *Machine Learning* (pp. 209-225). Academic Press.
https://doi.org/10.1016/B978-0-12-815739-8.00012-2

Kim, J. (2006). Infrastructure of the digital economy: Some empirical findings with the case of Korea. *Technological Forecasting and Social Change*, *73*(4), 377-389. https://doi.org/10.1016/j.techfore.2004.09.003

Koh, L., Orzes, G., & Jia, F. J. (2019). The fourth industrial revolution (Industry 4.0): technologies disruption on operations and supply chain management. *International Journal of Operations & Production Management*, *39*(6/7/8), 817-828.

Kolesnikov, A., Zernova, L., Degtyareva, V., Panko, I. V., & Sigidov, Y. I. (2020). Global trends of the digital economy development. *Opción: Revista de Ciencias Humanas y Sociales*(26), 523-540.

Laitsou, E., & Xenakis, A. (2023). The impact of digital development on human well being and vice versa.

Le Thanh, H., Phuc, H. N., Xuan, N. P., & Dinh, B. H. (2022). Influences of Digital Transformation on Life Expectancy and the Gender Gap in European Countries. *International Journal of Electronic Government Research (IJEGR)*, *18*(2), 1-28.

Lee, C.-W., & Kim, M.-S. (2019). The relationship between internet environment and life expectancy in Asia. *Review of Integrative Business and Economics Research*, *8*(2), 70-80.

Lee, N., & Clarke, S. (2019). Do low-skilled workers gain from high-tech employment growth? High-technology multipliers, employment and wages in Britain. *Research Policy*, *48*(9), 103803. https://doi.org/10.1016/j.respol.2019.05.012

Li, K., Kim, D. J., Lang, K. R., Kauffman, R. J., & Naldi, M. (2020). How should we understand the digital economy in Asia? Critical assessment and research agenda. *Electronic commerce research and applications*, *44*, 101004.

Limna, P., Kraiwanit, T., & Siripipatthanakul, S. (2023). The Growing Trend of Digital Economy: A Review Article. *International Journal of Computing Sciences Research*, *7*, 1351-1361.

Lind, N. (2019). A development of the human development index. *Social Indicators Research*, *146*(3), 409-423.

Liu, X.-d., Pan, F., Cai, W.-l., & Peng, R. (2020). Correlation and risk measurement modeling: A Markov-switching mixed Clayton copula approach. *Reliability Engineering & System Safety*, *197*, 106808. https://doi.org/10.1016/j.ress.2020.106808

Lyu, Y., Peng, Y., Liu, H., & Hwang, J.-J. (2022). Impact of digital economy on the provision efficiency for public health services: empirical study of 31 provinces in China. *International Journal of Environmental Research and Public Health*, *19*(10), 5978.

Makhmudova Dilbar, R. (2021). Tasks and solutions to improve small business in the development of the digital economy, *Conferencious Online*, 57-60.

Mallaboyev, N. (2023). The role of information and communication technologies in the development of the digital economy, *Development of pedagogical technologies in modern sciences*, *2*(6), 5-12.

Mao, X. (2023). Analysis of the influence path of digital infrastructure on economic development. *Advances in Economics Management and Political Sciences*, 25(1), 47-55. https://doi.org/10.54254/2754-1169/25/20230474

Mensah, I. K. (2019). Impact of government capacity and E-government performance on the adoption of E-Government services. *International Journal of Public Administration*.

Mohajan, H. (2019). The second industrial revolution has brought modern social and economic developments.

Mosadeghrad, A., Pour, R. A., Abolhasan, B. G. N., & Shahebrahimi, S. (2019). Impact of Human Development Index on mortality rates in Iran. *Iranian Journal of Epidemiology*, *14*(4).

Muralidharan, K., Shanmugan, K., & Klochkov, Y. (2022). The new education policy 2020, digitalization and quality of life in India: Some reflections. *Education Sciences*, *12*(2), 75.

Natalya, A. Y., Elena, S. Z., Natalya, V. A., & Vladimir, A. G. (2020). Model of Consumer Behavior during the Digital Transformation of the Economy. *Industrial Engineering & Management Systems*, *19*(3), 576-588. https://doi.org/10.7232/iems.2020.19.3.576

Nazaritehrani, A., & Mashali, B. (2020). Development of E-banking channels and market share in developing countries. *Financial Innovation*, *6*(1), 12.

Omrani, H., Alizadeh, A., & Amini, M. (2020). A new approach based on BWM and MULTIMOORA methods for calculating semi-human development index: An application for provinces of Iran. *Socio-Economic Planning Sciences*, *70*, 100689.

Ovcharov, A. O., & Terekhov, A. M. (2023). Building a country rating of digitalization of the economy based on the principal component analysis. *Voprosy statistiki*, 30(1), 58-69. https://doi.org/10.34023/2313-6383-2023-30-1-58-69

Pantelimon, F., Georgescu, T., & Posedaru, B. (2020). The impact of mobile e-commerce on gdp: A comparative analysis between romania and germany and how covid-19 influences the e-commerce activity worldwide. *Informatica Economica*, *24*(2), 27-41.

Patton, A. J. (2012). A review of copula models for economic time series. *Journal of Multivariate Analysis*, *110*, 4-18. https://doi.org/10.1016/j.jmva.2012.02.021

Prasetyani, D., Sangka, K., & Juwita, A. (2024). Constructing digital economy acceptance index (DEAI): A comparative analysis of developed and developing countries. International *Journal of Data and*

Network Science, 8(4), 2107-2118. http://dx.doi.org/10.5267/j.ijdns.2024.6.020

Pylypenko., Andrii, Shvets. (2024). Digital dimension of human capital development. *Ekonomìčnij vìsnik Dnìprovs'koï polìtehnìki*, 86:74-80. https://doi.org/10.33271/ebdut/86.074

Rehman, N. U., & Nunziante, G. (2023). The effect of the digital economy on total factor productivity in European regions. *Telecommunications Policy*, 102650. https://doi.org/10.1016/j.telpol.2023.102650

Ringnér, M. (2008). What is principal component analysis? *Nature Biotechnology*, *26*(3), 303-304. https://doi.org/10.1038/nbt0308-303

Safari-Katesari, H., Samadi, S. Y., & Zaroudi, S. (2020). Modelling count data via copulas. *Statistics*, *54*(6), 1329-1355. https://doi.org/10.1080/02331888.2020.1867140

Shevchenko, I., Lysak, O., Shyshak, A. Z., Mazur, I., Korotun, M., & Nestor, V. (2023). Digital Economy in a Global Context: World Experience. *International Journal of Professional Business Review: Int. J. Prof. Bus. Rev.*, *8*(4), 11.

Sitepu, E., Sembiring, M., Kia, A. D., & Nggebu, S. (2022). Education Transformation In The Digitalization Age As The Future Of The Nation. *Journal Of Applied Linguistics*, *2*(1), 8-16.

Skare, M., & Soriano, D. R. (2021). How globalization is changing digital technology adoption: An international perspective. *Journal of Innovation & Knowledge*, *6*(4), 222-233.

Stavytskyy, A., Kharlamova, G., & Stoica, E. A. (2019). The Analysis of the Digital Economy and Society Index in the EU. *TalTech Journal of European Studies*, *9*(3), 245-261. https://doi.org/10.1515/bjes-2019-0032

Taalbi, J. (2019). Origins and pathways of innovation in the third industrial revolution. *Industrial and corporate change*, *28*(5), 1125-1148.

Tondro, M., Jahanbakht, M., Rabbani, S. B., & Zaber, M. (2022). Does immergence of ICT focused institutions increase the pace of urban development? A provincial case study in Iran using data from the ground and above. 2022 IEEE Conference on Technologies for Sustainability (SusTech),

Trivedi, P. K., & Zimmer, D. M. (2007). Copula Modeling: An Introduction for Practitioners. *Foundations and Trends in Econometrics*, *1*(1), 1-111. https://doi.org/10.1561/0800000005

Voronkova, V., Nikitenko, V., Oleksenko, R., Andriukaitiene, R., Kharchenko, J., & Kliuienko, E. (2023). Digital technology evolution of the industrial revolution from 4g to 5g in the context of the challenges of digital globalization. *TEM Journal*, *12*(2), 732-742.

Wang, Z., & Shi, P. (2021). Research and Analysis on the Index System of Digital Economy in Anhui Province. *Complexity*, *2021*, 5535864. https://doi.org/10.1155/2021/5535864

Williams, L. D. (2021). Concepts of Digital Economy and Industry 4.0 in Intelligent and information systems. *International Journal of Intelligent Networks*, *2*, 122-129.

Yalcintas, A., & Alizadeh, N. (2020). Digital protectionism and national planning in the age of the internet: the case of Iran. *Journal of Institutional Economics*, *16*(4), 519-536.

Yan, J. (2023). Multivariate Modeling with Copulas and Engineering Applications. In H. Pham (Ed.), *Springer Handbook of Engineering Statistics* (pp. 931-945). Springer London. https://doi.org/10.1007/978-1-4471-7503-2_46

Yazdanpanah, M., Moradi, M., & Asgar Khani, A. M. (2023). Scientific and technological diplomacy and regional development of Iran. *World Politics*. (In Persian)

You, Z.-T., Zhong, M., Gao, Q., Wei, H.-X., & Zeng, X.-H. (2021). The impact of digital economy on residents' health: based on the perspective of population ageing. *Frontiers in Public Health*, *9*, 725971.

Zhang, W., Zhao, S., Wan, X., & Yao, Y. (2021). Study on the effect of digital economy on high-quality economic development in China. *PloS one*, *16*(9), e0257365.

Zhang, Z. (2023). The impact of the artificial intelligence industry on the number and structure of employments in the digital economy environment. *Technological Forecasting and Social Change*, *197*, 122881. https://doi.org/10.1016/j.techfore.2023.122881

Zhao, Y., Kong, X., Ahmad, M., & Ahmed, Z. (2023). Digital Economy, Industrial Structure, and Environmental Quality: Assessing the Roles of Educational Investment, Green Innovation, and Economic Globalization. *Sustainability*, *15*(3), 2377.