Research Article

A Multivariate Statistical Analysis on Digital Divide across Asia and Oceania Countries

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Abstract: The development of ICT acts as a catalyst for economic growth, yet, the digital disparities are presenting a threat by leaving some countries behind in the race to global competitiveness. Although numerous attempts have been made to analyze the digital gap in various regions, there hasn't been any detailed research for the Asia and Oceania countries. The purpose of this study is to analyze and observe the evolution of the digital divide in this region. The authors tackled the measurement of the digital divide among thirty-one countries of this region using multivariate statistical methods. Factor analysis was used to determine a small number of factors that summarize the set of digital development factors. Using cluster analysis, countries were clustered into five groups and were ranked from digital laggards to digital leaders. We observed the short-term digital divide evolution by drawing the path movements of these countries between the years 2011 and 2016 which showed a clear picture of what countries have improved their digital development scores in the past five years. At last, this research suggested some recommendations for policymakers to help them narrow the digital gap between their countries and 'digital leaders'.
Keywords: Digital divide, digital gap, digital diffusion, factor analysis, cluster analysis

1. Introduction

Under the traditional context of an economy, the prosperity index of any country was calculated considering physical capital (natural resources, machines, roads) and human capital (skilled labor). However, in a modern context, both developed and underdeveloped economies are now assessed based on ideas, knowledge, and ICT (Mitrović, 2015). These days, a country's performance is linked directly to the level, diffusion, and use of information and communication technologies. Moreover, the effective use of ICTs improves the economic prosperity, social development, and global competitiveness of a country.

For example, (Czernich, Falck, Kretschmer, & Woessmann, 2011) observed the direct relationship between the broadband penetration rate and GDP growth of OECD countries and found that there was an increase of 2.7% – 3.9% GDP per capita after introducing broadband technologies (1996-2007). Similarly, (Kongaut & Bohlin, 2014) analyzed the impact of broadband speed and concluded that a 10% increase in broadband speed resulted in a 0.8% increase in GDP per year. Hence there have been significant and revolutionary improvements in the spread of ICT over the last two decades. As a result, social media, web surfing, emails, and online job searching have now become one of the necessities for survival.

Seeing ICTs as a catalyst for economic growth, many governments have also come up with the induction of ICTs in their strategic plans. For example, the European Union (NewsEuropean, 2011) has decided to spend an additional one Billion Euros to invest in broadband and high-speed connectivity in rural areas. The European Union (EuropeanCommision, 2010) mentioned in their 2020 strategy the smart, sustainable, and inclusive growth for the European Economy and stated that ICT will help create around 1 million jobs in Europe and an increase of 850 billion euros in 10 years. In the same way, the US Department of Commerce's statistics reflects that ICT generally provides great economic benefits by reducing inflation and improving productivity (Rice & Katz, 2003). Yet, this boom in internet technologies has also resulted in digital disparities among certain regions and countries, representing a huge threat by leaving behind these countries in the race of global competitiveness.

Considering the threat of digital disparities for certain underdeveloped countries, at the World Summit of Information Society in December 2003, the heads of all countries agreed on doing their best to build a society where each individual should have access to the internet and use these technologies to have a positive impact on society (Berry, 2006). To achieve this goal, many barriers need to be overcome, and the first among them was eradicating the digital divide between countries. Since the internet is considered to be a crucial factor for economic growth, the uneven distribution of the internet within a country and across countries has caught the attention of many researchers and policymakers (Zhang, 2013). 'Digital Divide' was the terminology used to define this unequal distribution. Hence, just like ICT plays a decisive role in the economic growth of a country, in the same manner, the digital divide and disparities within and among countries can represent a threat to harnessing opportunities offered by ICTs (Vicente Cuervo & López Menéndez, 2006).

Keeping in mind the importance of ICTs in the economic development of a country, many authors have conducted research to eradicate the digital divide among various regions and countries. (Cruz-Jesus, Oliveira, & Bacao, 2012; Hilbert, 2016; Nishijima, Ivanauskas, & Sarti, 2017; Vicente Cuervo & López Menéndez, 2006; Vicente & López, 2011; Yuguchi, 2008) Nevertheless, there hasn't been enough work presenting a wide snapshot of the digital divide in Asia and Oceania countries, forming more than 60% of the world population (Population of Asia (2019) - Worldometers, 2019).

Shockingly, even though the ITU, OECD, and World Bank are releasing the ICT data for each year, no specific research has been conducted that would be useful for policymakers of this region to form the policies to bridge any digital divide between countries and within countries (Sharma & Mokhtar, 2006).

This research is the first of its kind taking account of data pertaining to the years of 2011 and 2016 for thirty-one countries in this region. Due to the unavailability of the data, the authors had to restrict their research to this number of countries but still, it covers all the main regions including Oceania, Far East Asia, SAARC, Middle East, and Central Asian countries. The main goal of this study is to answer the following questions:

- Whether or not, the digital divide exists among the countries of Asia and Oceania region?
- If yes, how to measure this digital divide, and what indicators should be taken into consideration while calculating it?
- Are there any cluster/group of countries that exhibit the same level of digital penetration & digital disparities?
- Whether these countries have successfully narrowed down the digital gap than others while seeing the digital evolution for a time slot of five years (2011-2016)?
- What are suggestions for policymakers to narrow the digital divide between these clusters?

To answer these research questions, the paper is organized as follows: Section-2 presents a literature review of the digital divide and the limitation of existing work done in the past, Section-3 develops a methodology to measure the digital divide and a detailed overview of the data and the determinants that are chosen. Section-4 shows the methodology implemented to analyze the digital gap using a factor and a cluster analysis, Section-5 presents the short term digital divide evolution (2011-2016), and Section-6 presents the recommendations for the policymakers to narrow down the digital gap and the last section i.e. Section-7 shows the conclusion of this research.

2. Literature Review

Policymakers, researchers, and world leaders have unanimously agreed that the digital divide represents a major threat to the realization of opportunities offered by ICT (Carlsson, 2004; Çilan, Bolat, & Coşkun, 2009). In this regard, several meaningful attempts have been made to define and analyze this issue. After conducting the literature review in-depth, it was concluded that over time, the topic of the digital divide has gone through various changes. Since the topic itself is complex and multidimensional, there is not a uniformity in terminologies related to the digital divide and in the determinants – the variables used to measure the digital divide.

This thorough review of the past studies and helped the authors in figuring out a) What variables to use in this research and b) What methodologies to perform, to measure the digital divide in Asia and Oceania region, and these findings will be discussed in the coming subsections. The next section is a detailed study of the work done in the past on the topic of the digital divide.

2.1. Digital divide concepts and determinants

The first and foremost problem in analyzing the digital divide is that there is no specific definition of the term itself. It is still unknown how and where the term 'digital divide' originated, yet it became a topic of interest in the early 1990s when computers and the internet became accessible to the common man (Eastin, Cicchirillo, & Mabry, 2015). Yet, to date, there is a lack of consistency in the terminology used, both for its type (binary, secondary, tertiary), as well as the determinants to be used to analyze it.

Most of the time, scholars refer to the same concept using different terminologies (Scheerder, van Deursen, & van Dijk, 2017). For example, (Eastin et al., 2015) described the digital divide as the uneven distribution of the internet. (Dewan & Frederick, 2005) referred to it as the binary distinction between those connected to the internet and those who aren't. Some of the authors call this binary level, i.e., access to the internet or not, as the first level digital divide (Bucy & Newhagen, 2004). Starting from the 21st century, a major proportion of the population in western countries has started to have an internet connection, and this binary access to the internet was not considered to be a criterion to analyze the digital divide. Hence, researchers have shifted their focus towards internet skills and outcomes as the base to define this divide.

Scholars had then started defining the second level of the digital divide, which focuses on the intensity and the way technologies have been used. Some authors defined the second-level digital divide based on internet skills (Scheerder et al., 2017) and technology usage (usage gap) (van Dijk, 2005). But many researchers asserted to define the digital divide more comprehensively, apart from internet access, skills, or usage (Selwyn, 2004). Some of them have given a third dimension to the digital divide based on beneficial outcomes of internet usage (Fuchs, 2009; van Dijk, 2005). This kind of digital divide presents even internet access and internet skills that lead to positive outcomes in a society (Stern, Adams, & Elsasser, 2009).

According to ITU, as more than half of the world's population has access to the internet (World Internet Users Statistics and 2019 World Population Stats, 2019), measuring the first and second types of the digital divide in this age will not show the true picture of the problem. Furthermore, in the era of IoT, AI, and Big Data, restricting the digital divide to mere access, use or skills will also not justify the aim of the research. Even though there is a need to redefine the digital divide based on AI & IoT penetration, getting the data for a huge number of countries is almost impossible (this could be one of the future works of this study). Therefore, research was restricted to the 3rd level of the digital divide and will take into account the variables of access, skills, and usage.

2.2. Methodologies to measure the digital divide

Given the importance of ICT in a social and economic development context, measuring the progress towards information society is very vital for each country (Vicente Cuervo & López Menéndez, 2006), yet there has not been any sort of research done in the Asia and Oceania region as a whole, compared to work done for other regions and continents. When talking about European countries, (Cruz-Jesus et al., 2012) analyzed the digital divide between twenty-seven European Union nations between 2008 and 2010. This research has been considered a great contribution since the authors saw the countries' performance during these three years and at the end gave their recommendations to policymakers as to which countries have been doing great, which countries have improved by decreasing the digital gap in three years, which countries are digital leaders, and which countries are digital laggards.

In the same manner, several other research has been done for European countries. (Vicente Cuervo & López Menéndez, 2006) first analyses the digital gap between fifteen European nations using multivariate statistical methods. The same authors (Vicente & López, 2011) extended their research to 27 European countries in 2011. Not only that, but they also tried to address the digital divide within each country. Some authors have attempted to capture the digital divide using composite indicators, also known as indices. Some authors have used factor analysis techniques to incorporate various dimensions of ICT development into an index(Bruno, Esposito, Genovese, & Gwebu, 2011). (Zhang, 2018) used extended DOI model to measure the impacts of the diffusion of frugal digital ICTs on the digital diffusion and divide.

(Mitrović, 2015) investigated the digital divide in western Balkan countries and their global economic competitiveness due to the adoption, use, and speed of ICT. Some other authors analyzed the level and diffusion of information and communication technology in African countries (Roycroft & Anantho, 2003) while others took into consideration the socio-demographic factors to analyze the digital gap in Latin American countries (Gray, Gainous, & Wagner, 2017). (Nishida, Pick, & Sarkar, 2014) looked over the digital gap within certain regions in Japan, (Sujarwoto & Tampubolon, 2016)'s work is limited to digital inequalities in Indonesia. (Abdullah, 2015) examined this gap in rural areas of Pakistan and so on.

Another vital limitation of existing research is the availability of uniform data for Asia and Oceania countries. Unlike the European Union, due to a lack of organization that should deal with collecting and organizing ICT related data, the comparative analysis of the digital divide in Asia and Oceania region has yet to be explored. This lack of uniform data for all countries also affects the determinants to be chosen while measuring the digital gap. Since there is always a tradeoff between the number of constraints to be chosen and the countries involved in the research, this is one of the reasons one rarely finds digital divide research done for the Asia and Oceania region.

The literature shows that ICT should be conceptualized as GPTs (general-purpose technology) while analyzing a digital divide (Carlsson, 2004). GPTs can be categorized as technologies that have the potential to positively affect various industries and social sectors (Doong & Ho, 2012), and since ICTs have been seen to greatly impact various sectors of our society, it is worth treating them as GPT while measuring the digital divide, which makes the digital divide a multi-dimensional issue (Cruz-Jesus et al., 2012). Furthermore, since the digital divide cannot be just measured by internet penetration rate, it should be considered as a multidimensional phenomenon (Vicente Cuervo & López Menéndez, 2006) hence multiple indicators will be used to calculate the ICT development of a country.

After going through the various methodologies to measure the digital divide, the authors concluded that the multivariate statistical methods are the perfect approach to measure this gap for this big region. To analyze the joint behavior of multiple variables, matrix correlation, PCA (Factor and Cluster Analysis) multivariate techniques were applied. Based on the ICT recommendations and past researches, various indicators were selected which will be referred to as 'digital divide determinants' or simply 'determinants' throughout this paper since the same terminology has been used in multiple other papers.

To analyze the digital divide in Asia and Oceania region, first, the factor analysis was used to find out a small number of factors that summarize the information contained in a set of economic, demographic, social, and ICT-related indicators. The reason to consider all these factors is that the literature review shows that all these factors somehow contribute toward the digital development of a country. Second, using cluster analysis, these countries were grouped based on digital development factors. As a result, the countries will be ranked as digital laggards or digital leaders.

3. Framework and Data

According to the OECD's recommendation, the selection of digital divide determinants depends on the type and goal of the study. These indicators take the shape of socio-demographic factors like gender, age, and race while measuring the internal or domestic digital divide, but when measuring the digital divide across different countries, they should refer to the aggregated national reality (Cruz-Jesus et al., 2012). The selection of these always comes with a trade-off between depth and breadth in the analysis, i.e., if more indicators are used, there will be a lower number of countries included in the research. The authors also faced the same issue while writing the paper. The initial analysis consisted of fifty-five countries in the Asia and Oceania region and fifteen indicators, but due to a lack of sufficient data, the authors were left with no other option than to reduce the analysis to thirty-one countries and ten variables.

The variables chosen for the research are all compatible with the recommendations from the OECD and have been used by many other researchers in the past. Out of ten indicators, nine indicators have been obtained from the "Measuring the Information Society Report 2017"(International Telecommunication Union, 2017) pertaining to the year 2016. One indicator, that plays a vital role in defining the digital development of a country, Secure Internet Servers, was taken from World Bank's website pertaining to the year 2016 ("Secure Internet servers (per 1 million people) | Data," n.d.). The fact that data has been taken from the official entities guarantees the results and reliability of the results of the research. Table 1 shows the variables and their abbreviations along with the values of the mean and standard deviation of the or thirty-one countries in the Asia and Oceania region taken into consideration for this research. For a detailed definition of each variable, please refer to Appendix 1.

Once again, the definitions of the variables have been taken from ITU's Measuring the Information Society Report (International Telecommunication Union, 2017).

Table.1. Acronyms and descriptions of digital divide variables used.

ICT Variables	Abbreviation	Mean	St. Deviation
Fixed-telephone subscriptions per 100 inhab.	FTS	19.12	16.21
Fixed-broadband subscriptions per 100 inhab.	FBS	14.07	11.65
Mobile-cellular prices (% GNI pc)	MCP	1.41	1.63
Fixed-broadband prices (% GNI pc)	FBP	3.18	3.99
Mobile-broadband prices 500 MB (% GNI pc)	MBP	0.91	0.56
Percentage of households with a computer	HC	59.01	29.12
Percentage of households with Internet access	HI	65.21	28.50
Percentage of individuals using the Internet	PIUI	63.55	25.64
Secure Internet servers (per 1 million people)	SIS	323.05	529.96
Active mobile-broadband sub. per 100 inhab.	AMB	83.98	41.92

Just like the work by other researchers (Cruz-Jesus et al., 2012; Vicente & López, 2011), the authors selected those indicators that represent not only the ICT infrastructure but also their penetration at different levels e.g., Individuals and Households. Furthermore, these variables had also been used in the past by other researchers to analyze the digital divide phenomenon. For example, (Bruno, Esposito, Genovese, & Gwebu, 2011; Nour, 2015; Wong, 2002; Yuguchi, 2008) used FTS and FBS, (Chinn & Fairlie, 2007; Corrocher & Ordanini, 2002) utilized price-related variables like MCP, FBP, and MBP, (Chinn & Fairlie, 2007; Cruz-Jesus et al., 2012; Várallyai, Herdon, & Botos, 2015; Vicente Cuervo & López Menéndez, 2006; Vicente & López, 2011) analyzed digital divide using HC, Hi, and PIUI, while (Cruz-Jesus et al., 2012) used SIS in their research.

In keeping the homogeneity, availability, and uniformity of the data for such a large set of countries, these variables are being taken into consideration to effectively measure ICT development. Table 2 shows all countries along with their value against the ten variables. The data has been collected from "Measuring the Information Society Report 2017" (International Telecommunication Union, 2017).

Table.2. Data collected for 31 countries in the Asia and Oceania region for the year 2016.

Countries	**FTS**	**FBS**	**MCP**	**FBP**	**MBP**	**HC**	**HI**	**PIUI**	**SIS**	**AMB**
Australia	33.8	30.4	0.3	1.1	0.4	85.9	88.5	88.2	1430.81	130.2
Azerbaijan	17.5	18.6	0.9	1.1	0.3	64.3	77.4	78.2	20.50	56.3
Bahrain	20.3	16.8	0.6	0.8	1	94.8	98	98	195.77	162.4
Bhutan	2.7	2.1	1.3	3.9	0.8	26	33	41.8	23.82	69.4
Brunei Darussalam	17.1	8.3	0.3	0.6	0.2	93	75	75	233.93	116.6
Cambodia	1.4	0.6	7.7	13.5	1.1	10.5	26	25.6	6.85	50.2
China	14.7	22.9	0.6	2.4	0.7	52.5	55.5	53.2	20.50	69.1
Hong Kong	58.6	35.7	0.2	0.6	0.3	81	82	87.3	962.71	104.6
India	1.9	1.4	1.8	4.8	1.9	15.2	22.6	29.5	7.82	16.8
Indonesia	4.2	2	3.3	10.6	1.4	19.1	47.2	25.4	10.11	34.2
Israel	41.6	28.1	1.1	1.1	0.5	81.1	75.7	79.8	293.24	93.4
Japan	50.6	31.4	1	0.6	1.5	81	97.2	92	1070.68	132.3
Jordan	5.2	5.8	1.6	7.8	1.3	53.1	79	62.3	24.01	125.6
Kazakhstan	23.2	13.9	0.4	0.6	0.5	76.2	84.4	76.8	30.96	78.9
Korea (Rep.)	56.1	41.1	1.2	1.5	1	75.3	99.2	92.7	2200.79	111.5
Lao P.D.R.	17.7	0.3	4.7	16.5	1.7	12.3	18.7	21.9	3.40	34.7
Malaysia	15.6	8.7	0.7	1.1	0.8	72.2	76.9	78.8	106.45	91.7
Maldives	5.8	8	1	3.5	1.2	71.1	54.7	59.1	102.86	72.7
Mongolia	7.6	7.6	0.8	2.1	1.6	23.6	23.6	22.3	31.05	57.1
New Zealand	37.9	33	0.2	1.8	0.4	86.6	85.7	88.5	1186.82	101.3
Oman	9.8	6.2	0.6	2.8	0.9	87.5	86.1	69.8	96.28	91.3
Pakistan	1.6	0.9	2	5	1.1	16.1	22.1	15.5	2.79	20.1
Philippines	3.7	5.5	3.2	7.1	2.1	34	39.1	55.5	14.77	46.3
Qatar	19.3	10.5	0.3	1	0.3	89	95.8	94.3	268.89	148.9
Russia	22.8	19.4	0.4	0.6	0.3	74.3	74.8	76.4	214.52	74.9
Saudi Arabia	12	10.8	0.7	1.1	1	69	94.6	73.8	57.63	78.5
Singapore	35	25.6	0.2	0.5	0.2	86.6	91.1	81	890.27	146
Sri Lanka	11.4	4.1	0.3	1.4	0.6	25.4	21.1	32.1	16.88	18.3
Turkey	14.3	13.6	3.4	1	0.6	58	76.3	58.3	80.08	66.8
UAE	23.4	13.3	0.2	0.5	0.5	91	94.3	90.6	390.85	156.7
Viet Nam	5.9	9.6	2.6	1.7	2	23.5	25.9	46.5	18.57	46.6

4. Results

4.1. Finding latent factors

Factor Analysis uses the correlation between multiple variables under consideration to find the quiescent factors within them (Spicer, 2004). Factor analysis can be used in two ways: exploratory or confirmatory. The first one does not set a priory the exact number of factors to be extracted (Vicente & López, 2011) while the latter does. In this research, since the authors did not know the underlying dimensions of the indicators, so the first approach was applied. The exploratory approach is comprised of four steps: first, the correlation matrix is formed to confirm that the factors have been sufficiently correlated. Second, the method to extract the factors has to be determined (the methods include principal component analysis, principal axis analysis). Third, the extracted factors should be evaluated to determine how well they fit the data, and finally, the extracted factors should be named. The Correlation Matrix that was formed through the help of SPSS Statistics, is shown in Table 3.

Table.3. Correlation matrix.

	FTS	**FBS**	**MCP**	**FBP**	**MBP**	**HC**	**HI**	**PIUI**	**SIS**	**AMB**
FTS	**1.00**	0.92	-0.40	-0.43	-0.44	0.63	0.64	0.70	0.83	0.56
FBS	0.92	**1.00**	-0.46	-0.55	-0.45	0.65	0.66	0.73	0.84	0.54
MCP	-0.40	-0.46	**1.00**	0.83	0.51	-0.67	-0.55	-0.60	-0.30	-0.49
FBP	-0.43	-0.55	0.83	**1.00**	0.54	-0.68	-0.58	-0.66	-0.32	-0.47
MBP	-0.44	-0.45	0.51	0.54	**1.00**	-0.66	-0.58	-0.56	-0.27	-0.47
HC	0.63	0.65	-0.67	-0.68	-0.66	**1.00**	0.93	0.94	0.48	0.84
HI	0.64	0.66	-0.55	-0.58	-0.58	0.93	**1.00**	0.94	0.53	0.84
PIUI	0.70	0.73	-0.60	-0.66	-0.56	0.94	0.94	**1.00**	0.57	0.85
SIS	0.83	0.84	-0.30	-0.32	-0.27	0.48	0.53	0.57	**1.00**	0.51
AMB	0.56	0.54	-0.49	-0.47	-0.47	0.84	0.84	0.85	0.51	**1.00**

Table 3 shows the correlation matrix, and all variables can be seen to have at least one correlation coefficient with an absolute value greater than 0.6. This shows that the variables are strongly correlated to each other and that the factor analysis can be performed. To confirm the appropriateness of the factor analysis, many authors prefer several other tests, such as the Bartlett test of sphericity and the Kaiser-Mayer-Olkin (KMO) measure test also called a measure of sampling adequacy (MSA).

Although the correlation matrix provides first insight of the correlation structure between the variables, the final decision should be made after confirming the values of the KMO/MSA test, along with Bartlett Test(Cruz-Jesus et al., 2012; Vicente & López, 2011). While performing the KMO/MSA test, if the value of the KMO test value is below 0.50, the adequacy of the correlation is considered to be 'unacceptable'. KMO test value about 0.80 is thought to be 'meritorious' while above 0.90 is said to be 'marvelous'(Jolliffe, 2005).

In the case of the Bartlett test, the null hypothesis states that the correlation matrix is an identity matrix that is there is no correlation between the variables under consideration. Table 4 shows the values of both the tests. The KMO test with the value of 0.8739 means, the correlation is meritorious. On the other hand, Bartlett's test with a value of 334 and an estimated probability of less than 1 percent shows that the null hypothesis should be rejected (Tobias & Carlson, 1969). Hence, based on these two tests, it is shown that correlation exists among the variables used.

Table.4. KMO and Bartlett test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.873932297
Bartlett's Test of Sphericity	Approx. Chi-Square	334.1937343
	df	45
	Sig.	8.0696E-46

After validating the data for the factor analysis, the next step is to determine how many factors are to be extracted. Of all methods available, the most widely used are the ones based on the Eigenvalues and Percentage of Variance. For the Eigenvalues criterion, the researchers state that the factors with eigenvalues greater than 1 should be retained, while the cumulative percentage of variance criterion says that all the factors should account for 70%-80% of the total variance of the original variables. The result of factor analysis containing Eigen values, % of Variance, and cumulative % of Variance is shown in Table 5.

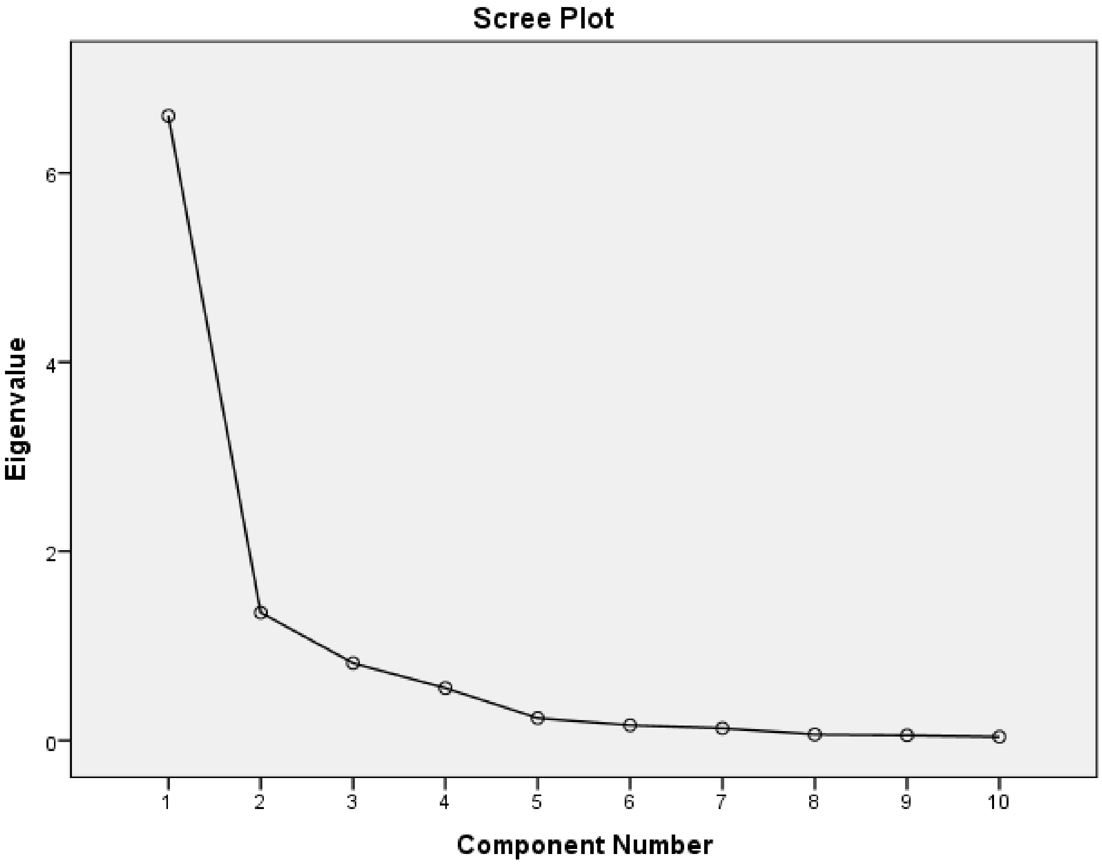
Table.5. Result of factor analysis

	Eigen Value	% of Variance	Cumulative %
1	**6.60**	**66.04**	**66.04**
2	**1.35**	**13.51**	**79.55**
3	0.82	8.17	87.71
4	0.55	5.52	93.24
5	0.24	2.35	95.59
6	0.16	1.60	97.19
7	0.13	1.28	98.47
8	0.06	0.62	99.09
9	0.05	0.54	99.63
10	0.04	0.37	100.00

In this analysis, as seen in Table 5, it can be seen that two of the factors have eigenvalues greater than 1. Usually while performing factor analysis, only those factors are retained which have eigenvalues greater than 1 and cumulative % of variance greater than 80 (Vicente & López, 2011). In this analysis, the two factors with eigenvalues greater than 1 account for 79.55% i.e. almost 80% of the covariance, so the authors decided to keep the 2 factors.

The extraction of 2 factors has also been validated with the help of the scree plot as drawn in Figure 1. Scree plots show a fraction of total variance that is explained by each factor extracted in the factor analysis. As per the rule of thumb by statisticians, the only number of factors to be retained should be above the scree or retaining the factors until the point from where the curve starts leveling off. As it is visible from Figure 1, that the curve stops dropping off after the 2nd factor, hence the number of extracted factors is two.

Figure.1. Extraction of factors using scree plot.



The next step is to define each factor in terms of the original variables. Since the purpose is to reduce the complexity of the analysis, the rotation of the factors' technique is used to determine the variance of the variables both of these factors explain. There are multiple rotation techniques, but the one used in this research was varimax rotation. Table 6 shows the results of the varimax rotation.

Table.6. Varimax rotated factor matrix.[a]

	Factor 1	**Factor 2**
HC	0.85	0.44
MCP	-0.83	-0.11
FBP	-0.83	-0.17
PIUI	0.76	0.57
HI	0.75	0.52
MBP	-0.71	-0.19
AMB	0.67	0.49
SIS	0.13	0.93
FTS	0.30	0.90
FBS	0.36	0.87
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.		
a. Rotation converged in 3 iterations.		

The Varimax Rotated matrix takes us to the final step, which is to name each of these factors. From Table 6, it is visible that Factor 1 has significant positive loadings on Percentage of Individuals using Internet, Percentage of households with computer, Percentage of households with Internet access, Active mobile broadband subscriptions and negative loadings on the Mobile-cellular prices (% GNI pc), Fixed-broadband prices (% GNI pc), Mobile-broadband prices 500 MB (% GNI pc). Hence Factor 1 can be related to *Digital Diffusion and Digital Cost*. On the other hand, Factor 2 has positive loadings on the Fixed-broadband sub. per 100 inhabitants, Fixed-telephone sub. per 100 inhabitants and Secured Internet Servers, so it can be named as *Digital Infrastructure*.

Since asymmetries between countries will be measured based on these 2 factors, there are certain meanings associated with them. First, 'Digital Diffusion and Digital Cost' shows the spread of technology into the masses having positive loadings on HC, PIUI, HI, and AMB, while negative loadings on the MCP, FBP, and MBP. Therefore, a positive value of factor score for digital diffusion will mean that the internet and related digital technologies are well adopted by the population. On the other hand, the negative loading means that the higher value of these indicators is an obstacle towards digital diffusion. Second, 'Digital Infrastructure' includes the tools and equipment necessary for the information technology to spread within a country, region, or organization. Since it has positive loadings on FTS, FBS, and SIS, once again, a positive value of factor score along with this dimension will show that the digital infrastructure is very strong in the countries of that cluster.

The extracted factors also have certain implications and utilization for policymakers. If policymakers have to form policies based on *Digital Diffusion and Digital Cost* factor, they should come up with programs to increase the diffusion of the internet and adoption by the population. For example, opening certain youth empowerment, improving digital literacy, encouraging multilingualism, and implementing 'zero-rating programs' (West, 2015). Moreover, to provide cheaper internet access to people, policymakers should focus on reducing internet packages costs, keeping connectivity taxes low, making the licensing fees affordable, and promoting competition (West, 2015).

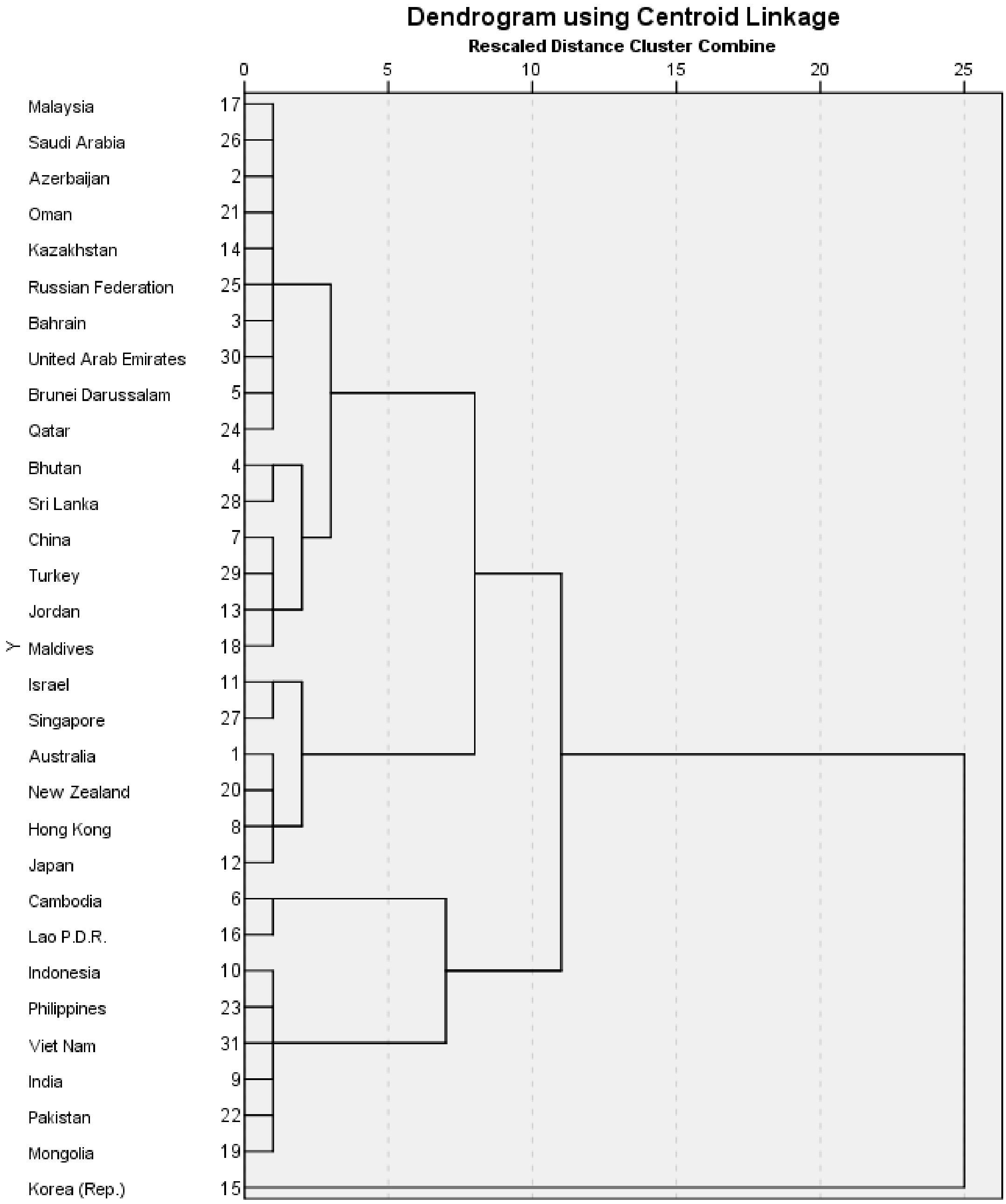
On the other hand, to improve the digital infrastructure of a country, policies should be formed to improve network efficiency, expanding digital infrastructure, and making effective use of the spectrum. The policy recommendations for the different clusters of countries will be provided in Section-6 of the research.

After calculating a certain number of factors from the given variables, the next step is to cluster countries with similar ICT properties described by the selected indicators, both for the factors and the original variables, while the methodology used for both cases is similar. First, the authors ran a hierarchical procedure to generate the number of clusters that depend on the data. In the case of hierarchical procedures, the number of clusters to be extracted depends on the distance measurement and the kind of algorithm used. For this analysis, the authors used a centroid method, and for the distance measurements, the Euclidean distance and squared Euclidean distance approach was taken into consideration. All of these approaches returned similar results.

4.2. Cluster analysis using factor scores

The solution based on a hierarchal method for the cluster analysis is given by the dendrogram in Figure 2.

Figure.2. Dendrogram for digital divide across Asia and Oceania countries.



The cluster analysis does not always produce the same solution, and it depends on the kind of distance measure and linkage rules. For our research, we used two distance measures of the Euclidean distance and Square Euclidian Distance techniques, and both of them formed the same clusters. The linkage rule that we selected was the centroid method. If cluster analysis is conducted using hierarchical procedures, the number of clusters to be extracted depends on the researcher’s choice. In our case, Figure 2, shows the graphical representation of the solution. If we mark the dendrogram with a broken line at position 5, we will have five clusters. On the other hand, marking the figure at position 10 gives only two clusters, which is a small number. Hence, we marked the dendrogram at position 5. Figure 2 is the graphical representation while Table 7 is the tabular representation of these five clusters.

Table.7. Cluster of countries using factor scores.

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
N = 6	**N = 1**	**N = 16**	**N = 2**	**N = 6**
Australia	Korea (Rep.)	Azerbaijan	Cambodia	India
Hong Kong		Bahrain	Lao P.D.R.	Indonesia
Israel		Bhutan		Mongolia
Japan		Brunei Darussalam		Pakistan
New Zealand		China		Philippines
Singapore		Jordan		Viet Nam
		Kazakhstan		
		Malaysia		
		Maldives		
		Oman		
		Qatar		
		Russia		
		Saudi Arabia		
		Sri Lanka		
		Turkey		
		UAE		

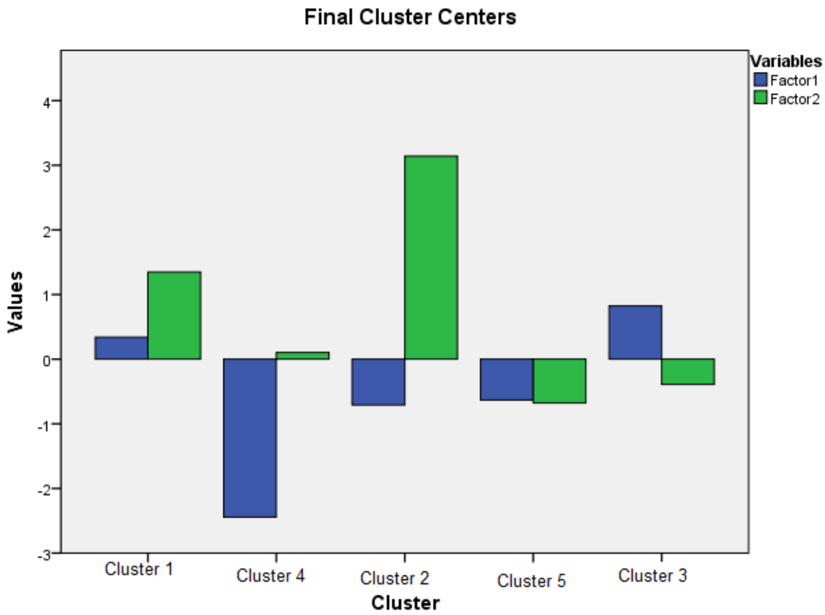
We computer the factor scores of each country by multiplying its ICT variable's value to the values given in the component score coefficient matrix (refer to Appendix 3 for the factor score values for the year 2016). Table 8 shows the mean factor scores of each cluster.

Table.8. Mean of factor score values of each cluster.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
	N = 6	**N = 1**	**N = 16**	**N = 2**	**N = 6**
Factor 1	0.34	-0.71	0.60	-2.44	-1.01
Factor 2	1.35	3.14	-0.47	0.10	-0.66

The robustness of these results was also evaluated using non-hierarchical techniques. The authors used the K-means algorithm for this purpose and the results generated by the K-means algorithm were the same as with the centroid method, which proved the validity of the clusters and their members. Figure 3, shows the bar chart of cluster analysis centers calculated using the K-means algorithm proving the validity of five clusters.

Figure.3. Bar chart of cluster analysis centers using K-means algorithm.



With the help of Table 8, we can name the clusters according to their factor scores. Cluster 1 showing the positive loading on both the factors i.e. Digital Infrastructure and Digital Cost + Diffusion, hence this cluster be named as‘digital leader’. Cluster 2 shows the highest value on Factor 2 yet it has negative loading on Factor 1 (due to the high digital cost), so it is named as ‘digital runner-up’. On the other hand, although Cluster 3 shows moderate values for factors 1 while a negative value of Factor 2, so we called it ‘digital follower’. Compared to the first three clusters, Cluster 4 has the lowest value on Factor 1, yet a positive value on Factor 2 making it called the ‘Infrastructure focused’ group. Cluster 5 shows the negative values on both the factors which makes us name it the ‘digital laggard’.

Figure. 4. Cluster analysis on factor scores.

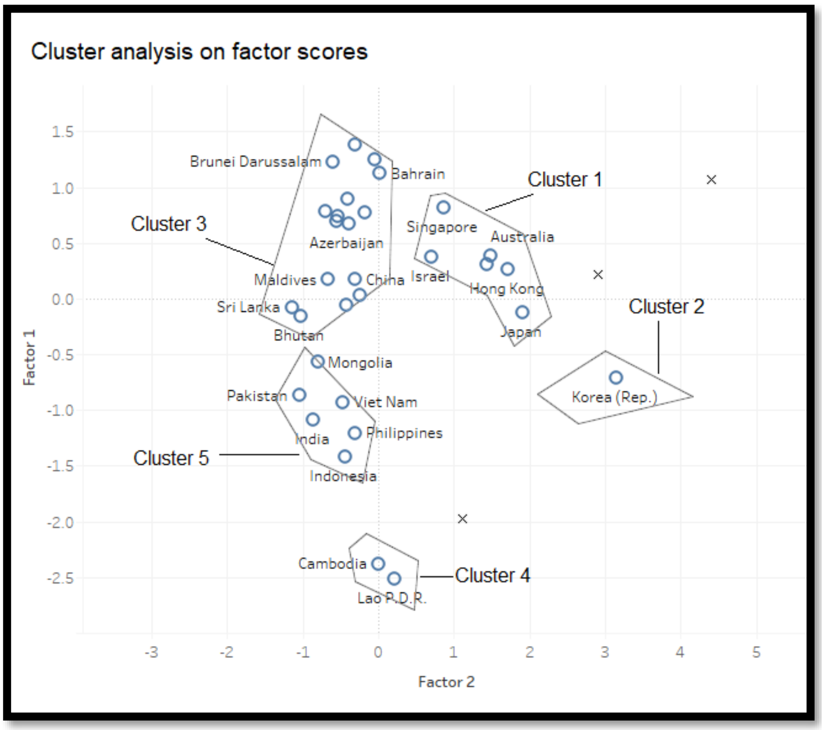


Figure 4 shows the visual representation of these clusters drawn along the two axes using their factor scores. Some very useful and interesting facts can be drawn from the figure. First, a very interesting result is derived from Cluster 2 i.e. Korea. No doubt, Korea has the highest value of digital infrastructure and digital diffusion, yet the cost of accessing the ICT related services is high compared to other developed countries of Cluster 1. Second, currently, only the Cluster 1 countries have positive loadings and Cluster 5 countries have negative loadings on both the factors. Cluster 3 countries, having negative loadings on Factor 2 shows that the cost to access the internet is high that ultimately affects digital diffusion. On the other hand, citizens of Cluster 4 countries enjoy low digital costs, but the poor digital infrastructure is the constraint for the digital gap between this cluster and others.

5. Short term digital divide evolution (2011-2016)

5.1. Dynamic pattern of the digital divide

Since we have validated the suitability of our derived latent factors, now the last step is to analyze the short-term digital divide evolution for the years between 2011 and 2016. We will draw the path movement of each country using its factor scores along both the axis. For this purpose, we gathered the data for all the variables of each country for the year 2011 and had to perform factor and cluster analysis from scratch.

One thing, that would be important to mention here is that we were unable to gather the data for the price-related variables. Since we didn't want to compromise the analysis, to overcome the values of missing variables, we used the same values of MCP, FBP, and MBP as those obtained for 2016. This move has also been supported by few other researchers like (Cruz-Jesus et al., 2012) who also experienced the unavailability of 'data-related problems' for past years and used the same strategy to overcome the issue. Hence it would help us in drawing an unbiased conclusion of the analysis. The data gathered for the years 2011 is given in Table 9 and was collected from "Measuring the Information Society" (International Telecommunication Union, 2012)

Table. Data collected for 31 countries in the Asia and Oceania region for the year 2011

Countries	FTS	FBS	MCP	FBP	MBP	HC	HI	PIUI	SIS	AMB
Australia	47.03	24.70	0.3	1.1	0.4	82.60	78.90	79.49	2027.80	42.80
Azerbaijan	18.41	10.65	0.9	1.1	0.3	24.90	39.50	50.00	4.69	21.50
Bahrain	21.63	22.81	0.6	0.8	1	90.00	76.80	77.00	122.04	9.50
Bhutan	3.71	1.79	1.3	3.9	0.8	9.10	8.10	14.40	5.40	1.00

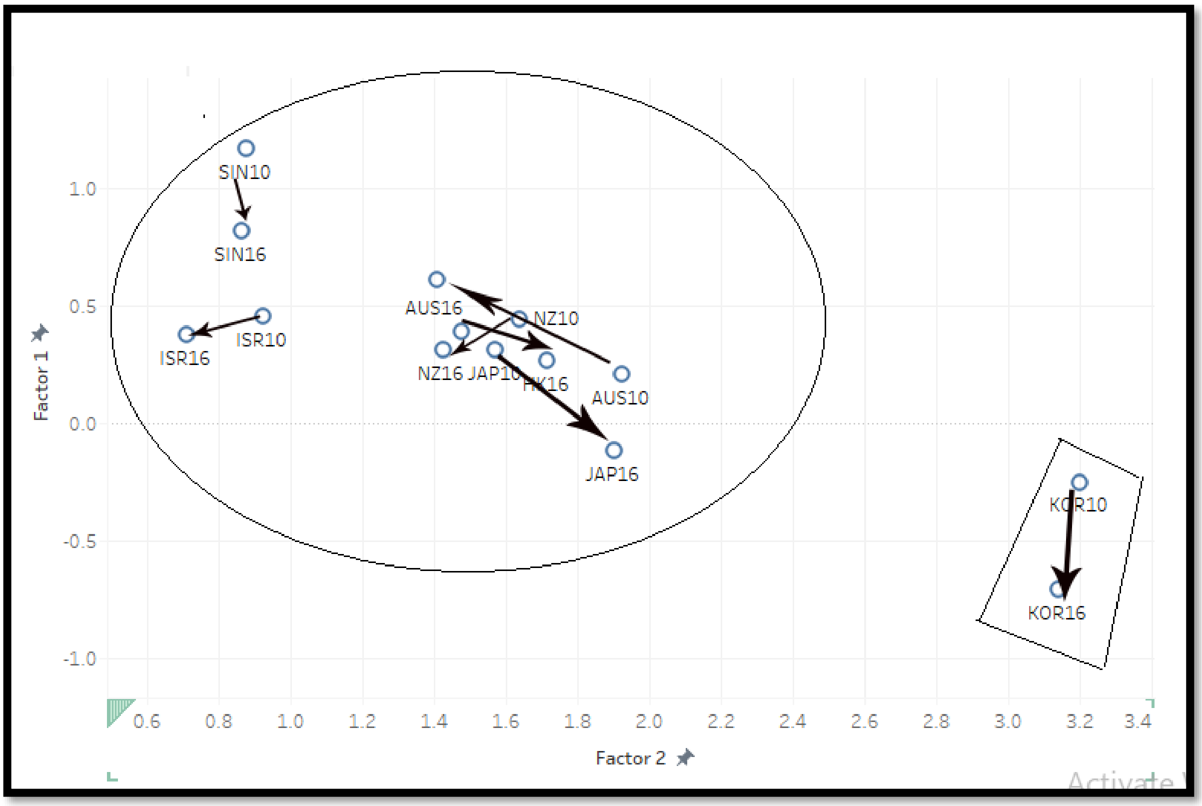
Brunei Darussalam	20.26	5.88	0.3	0.6	0.2	83.20	69.00	56.00	116.75	6.30
Cambodia	3.65	0.15	7.7	13.5	1.1	4.90	2.80	3.10	2.48	2.20
China	20.85	11.44	0.6	2.4	0.7	38.00	30.90	38.30	2.43	9.50
Hong Kong	61.45	32.54	0.2	0.6	0.3	80.80	79.60	72.20	570.45	51.80
India	2.63	1.07	1.8	4.8	1.9	6.90	6.00	10.07	2.84	1.90
Indonesia	15.72	1.11	3.3	10.6	1.4	12.00	7.00	12.28	3.34	22.20
Israel	46.24	24.83	1.1	1.1	0.5	79.00	71.00	68.87	470.14	41.00
Japan	50.32	27.78	1	0.6	1.5	86.00	84.40	79.05	743.84	93.70
Jordan	6.14	3.92	1.6	7.8	1.3	50.80	35.40	34.90	20.59	4.90
Kazakhstan	25.62	7.17	0.4	0.6	0.5	50.00	48.00	50.60	6.34	38.40
Korea (Rep.)	59.24	35.90	1.2	1.5	1	81.90	97.20	83.76	2488.25	105.10
Lao P.D.R.	1.70	0.10	4.7	16.5	1.7	7.80	4.20	9.00	1.26	0.60
Malaysia	15.79	8.75	0.7	1.1	0.8	64.10	61.40	61.00	54.86	12.30
Maldives	6.42	4.70	1	3.5	1.2	62.90	28.90	34.00	71.97	17.40
Mongolia	6.79	3.41	0.8	2.1	1.6	25.20	9.00	12.50	13.76	12.70
New Zealand	42.55	26.66	0.2	1.8	0.4	87.40	83.30	81.23	1605.16	53.00
Oman	8.88	2.42	0.6	2.8	0.9	58.00	38.90	48.00	46.95	37.80
Pakistan	3.28	0.67	2	5	1.1	11.00	6.70	9.00	1.13	0.30
Philippines	3.73	1.88	3.2	7.1	2.1	15.10	15.00	29.00	7.51	3.40
Qatar	15.83	8.43	0.3	1	0.3	88.30	83.60	69.00	120.90	61.00
Russia	30.82	12.31	0.4	0.6	0.3	57.10	46.00	49.00	26.93	47.90
Saudi Arabia	16.41	6.91	0.7	1.1	1	62.80	60.50	47.50	21.43	40.40
Singapore	38.99	27.21	0.2	0.5	0.2	86.00	85.00	71.00	607.29	110.90
Sri Lanka	17.76	1.77	0.3	1.4	0.6	13.60	8.10	15.00	6.20	2.30
Turkey	20.72	10.34	3.4	1	0.6	48.50	42.90	43.07	142.95	8.80
UAE	21.05	10.00	0.2	0.5	0.5	77.00	67.00	78.00	164.08	21.70
Viet Nam	11.38	4.29	2.6	1.7	2	16.00	14.00	35.07	4.60	18.00

We used the same techniques of factor and cluster analysis as done for the year 2016. The factor score values for each country for the year 2011 are given in appendix 2.

5.2. Digital divide structure in 2011 vs 2016

Comparing factor score values for the years 2011 and 2016, some useful insights can be drawn. To better show the countries' comparison on the graph, countries' acronyms are used rather than full names. The list of countries' acronyms is given in appendix 4. Figure 5 shows the movement of countries of Cluster 1 and Cluster 2 in two dimensions of the digital divide between these five years. Since we have kept the digital cost values for the year 2011 similar to 2016, movement along the Factor 1 might not be useful, yet meaningful results can be seen along with the Factor 2 axis. It can be seen that Australia did the worst among all these countries while talking about digital infrastructure, as its value dropped from 1.92 to 1.48. This result can be proved by seeing the original values of FTS, FBS, and SIS values. On the other hand, Japan’s digital infrastructure has significantly improved in these 5 years.

Figure. 5. Short term evaluation of Cluster 1, 2.



In the same way, seeing the countries in Cluster 3, we also see that these digital followers have significantly improved in the dimension of digital infrastructure in these five years. Yet some policy recommendations have been suggested for these countries along with the digital laggard cluster that will be presented in Section 6. Figure 6 shows the movement of countries of Cluster 3 between these five years, in two dimensions of the digital divide.

6. Recommendations for policymakers

At last, some policy actions can be proposed for policymakers in these countries on how to bridge this gap between their countries and digital leaders. In particular, all clusters would have a different approach to follow.

Cluster 2, being the digital leader, shows the lower digital cost and very positive values for digital infrastructure and digital diffusion, so all the countries should strive to match their digital profiles with this cluster. On the other hand, Cluster 1 i.e., Korea shows the highest values for digital infrastructure, but also revealed the fact that the price of internet access and services is very high compared to others. Hence, join the list of digital leaders, the Korean government should adopt the policy to provide internet at better prices or with better packages. This finding can also be provided with the recent research conducted in March 2019, which states that South Korea has one of the most expensive mobile data plans where prices could go up to $15 for a gigabyte of mobile data ("The Cost Of Mobile Internet Around The World [Infographic]," 2019).

Cluster 3 shows the lowest value of the digital infrastructure. Thus, the government should make policies to improve network efficiency and digital infrastructure. An interesting finding of this cluster was that almost all the Middle East countries fell into this group (Saudi Arabia, Qatar, UAE, Lebanon, Oman, etc). Other researchers also pointed out the fact that the cost is not a problem in Arab countries, but the lack of proper infrastructure. (Siegele, 2019) has proved that for the factor of 'population with active mobile-broadband subscriptions', the Arab States (54.9%) is ranked at the second bottom place after Africa (24.8%).

Cluster 4, infrastructure-focused, has the lowest values of the digital diffusion factor and also negative values for the digital infrastructure. On the other hand, surprisingly, the digital cost is not a factor, being the reason for the digital gap of this cluster since people bear very small digital costs. Hence, the government should focus on opening some youth empowerment programs to improve the digital diffusion dimension.

Cluster 5, being a digital laggard, has shown a poor score on all factors, but most importantly, it has the highest values of the Digital Cost factor, which means that people in these countries bear high costs to access the internet. This is one of the reasons for having a vast digital gap between these countries and other countries. No doubt, the government needs to improve the ICT infrastructure and focus on wireless penetration to the people. Above all, the government in these countries needs to decrease the price that people pay to access internet services.

India has started taking a great step towards opening up programs to educate adults (especially people from rural areas) on how to use the internet. Some of the worth mentioning programs that the government of India has launched to combat digital illiteracy are eSeva and National Knowledge Network (West, 2015).

Other than the Asia and Oceania countries, Mexico can be taken as an example (West, 2015), where the government agency Federal Telecommunications Institute is bringing down telecommunication costs by promoting competition, removing entry to the barrier, and allowing new firs to utilize the lines of existing operators.

7. Conclusion

In this research, the authors tried to analyze the digital divide using multivariate methods. Due to a lack of uniform data for a large number of countries, this analysis was restricted to thirty-one countries and ten determinants. First, the authors performed factor analysis to explore the latent factors out of these ten determinants. Based on Factor Analysis, it was found that the digital divide appears to have s independent dimensions: *Digital Diffusion and Cost* and *Digital Infrastructure.* Moreover, factor analysis also helps to find countries with similar digital profiles. This technique helps the authors to answer the first question of this research.

The cluster analysis, on the other hand, was performed to answer the next two research questions i.e. measuring the digital divide and finding countries of the Asia and Oceania region with similar digital profiles. Cluster Analysis allowed the authors to group countries with similar digital profiles, and it was seen that the digital divide does exist among such clusters. The cluster analysis technique resulted in the formation of five clusters that were named 'digital laggards', 'infrastructure-focused, 'digital followers', 'digital runner-up', and 'digital leaders.

Although this study is very useful in seeing the existing digital gap between the countries of Asia and Oceania region, there were certain limitations to this research. The first thing to note is that the analysis is done based on the data for the years of 2011 and 2016 as the data for the very recent years are not available for this big number of countries. Once the recent and updated data is available for public use for researchers, this kind of multivariate analysis can easily determine how well or bad a country has done to bridge the gap in these few years.

Another limitation of the research was the number of factors used for the analysis of the digital divide. As mentioned earlier, there is always a trade-off between the depth and width of the analysis. Since the authors wanted to analyze the big picture in the Asia and Oceania region, choosing a big number of countries restricted this study to ten determinants. Due to the lack of data for many under-developing countries, accessing data was a big hurdle.

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