ARE THE REGULATIONS IN FORCE IN LINE WITH THE DEVELOPMENT OF ICT?*

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Abstract

This study aims to examine whether the existence of Information and Communication Technologies (ICT) regulations in force are parallel to ICT development levels in economies. By covering the most recent indicators on the subject, the study first uses a hierarchical clustering methodology to classify 137 economies in terms of ICT development in 2015. After that; it compares statistical findings from the cluster analysis to the level of regulations by their existence to explore whether countries in the same cluster have similar ICT regulation levels. The empirical evidence shows that the countries in the same cluster mostly have similar economic development levels, yet the levels of ICT regulations within clusters are diversified. Even though some parallelism between ICT regulation and ICT development levels exist; exceptions, which signal heterogeneity, are apparent within clusters. Thus, the study finds out that ICT regulation is not directly but partially in line with the development of ICT.

Keywords: ICT, ICT Development, ICT Regulation, Clustering Analysis, Hierarchical Clustering.

JEL Codes: O14, O57, L50, L86, C38

YÜRÜLÜKTEKİ DÜZENLEMELER İLE BİLGİ VE İLETİŞİM TEKNOLOJİLERİNİN GELİŞİMİ BİRBİRİNE PARALEL Mİ?

Özet

Bu çalışmada, ekonomilerde Bilgi ve İletişim Teknolojileri (BİT) alanında yürürlükte bulunan yasal düzenlemeler ile bu ekonomilerdeki BİT gelişmişlik düzeyinin birbirine paralel olup olmadığı incelenmektedir. Konuyla ilgili en güncel göstergeler dikkate alınarak, ilk olarak hiyerarşik kümeleme metodolijisi kullanılmış ve 137 ekonomi 2015 yılındaki BİT gelişmişliklerine göre sınıflandırılmıştır. Bu analizden elde edilen istatistiksel sonuçlar ile her bir kümede yer alan ekonomilerin BİT düzenlemeleri açısından sahip oldukları düzey karşılaştırılmıştır. Bu karşılaştırmanın amacı, BİT gelişmişliğine göre benzer durumda olan ekonomilerde, yürürlükte olan BİT düzenlemeleri açısından da bir benzerlik bulunup bulunmadığının belirlenmesidir. Ampirik bulgular aynı kümede yer alan ülkelerin ekonomik gelişmişlik bakımından da benzer olduğunu göstermekte olsa da BİT alanındaki düzenlemelerin seviyesi açısından çeşitlilik gösterdiğini ortaya koymaktadır. Kümelerde BİT gelişmişliği ve düzenlemeler açısından benzerlik gösteren ekonomiler bulunmasına karşın; kümenin heterojen olduğuna işaret eden önemli istisnalar bulunmaktadır. Bu nedenle yürürlükteki düznlemelerin BİT gelişimi ile doğrudan değil, kısmen örtüştüğü sonucuna varılmıştır.

Anahtar Kelimeler: BİT, BİT Gelişimi, BİT Düzenlemeleri, Kümeleme Analizi, Hiyerarşik Kümeleme.

JEL Sınıflaması: O14, O57, L50, L86, C38

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1. Introduction

Digitalization of the economy and society has resulted in a rapid expansion in Information and Communication Technologies (ICT) globally in the last decades (UNCTAD, 2017). As digitalization has a growing role in economies, ICT is accepted as one of the factors that directly contribute positively to economic growth and development (Alderete, 2017; Stanley et al., 2018). Therefore, the topic attributes particular attention in development studies and requires a comprehensive examination.

As ICT gains higher importance for economies, designing regulations and making them in force becomes crucial. Regulations enable a stronger economic environment by setting rules, law, and procedures; all of which is expected to contribute positively to economic growth and development. Thus, the matter plays a key role in ICT development as the existence of appropriate regulations ensures a stronger ICT eco-system (Katz and Callorda, 2018). However, the topic of ICT regulation remains disconnected from other aspects of ICT in terms of economic development; such as access, usage, and infrastructure.

This study aims to contribute to the literature by connecting ICT regulation and ICT development. ICT development can be measured with various indicators. In addition to that, since the topic is a dynamic one, new indicators have been developing rapidly. These issues make the topic complicated to analyze. To overcome this problem; ITU (2019a) revised all indicators and listed the most recent indicators on a publication called *The ICT Development Index (IDI): Methodology, Indicators, and Definitions*. We use ICT development indicators from the most recent ones published in the mentioned report.

The contribution of this study to the literature is twofold. First, it aims to contribute to the literature by using the most recent indicators that represent the usage, access, and infrastructure to determine countries' level of ICT; and classifying them with accurate indicators. After that, the study focuses on regulations, which started to gain importance recently and accepted as a crucial factor for ICT development today. Thus, this study aims to fill the second literature gap by comparing the countries' level of ICT with their regulations and examining the relationship between them.

As a first attempt to connect regulations and development aspects of ICT, this study seeks an answer to the following research question: "Are the regulations in force in line with the development of ICT in economies?". By using the hierarchical clustering approach as a methodology on cross-sectional data in 2015, the study classifies 137 countries into clusters. These countries are clustered depending on seven ICT indicators, which are: individuals using the internet, households with a personal computer, households with internet

access at home, mobile broadband subscriptions, international internet bandwidth, mobile network coverage, and secure internet servers. According to ITU (2019a) and WEF (2016), these indicators serve as proxies for access and usage of ICT, and ICT infrastructure levels for countries.

The study then focuses on the ICT regulation tracker, an indicator released by ITU (2019b). This indicator measures the existence of ICT regulations and legislations in countries and then provides a score for each. The study compares the ICT regulation scores with the empirical findings from the cluster analysis and examines whether ICT regulations in force are in line with ICT development for these 137 countries. The ultimate aim of this study is to examine whether the ICT development level of economies is parallel to their regulatory framework.

The rest of the study is organized as follows: section two presents a literature review; section three provides the theoretical background of hierarchical clustering methodology and describes data; section four presents the findings, and section five concludes.

2. Literature Review

This stuıdy is the first to examine how ICT regulations and ICT development levels show parallelism with each other for a large cross-section of economies, to the best of the authors' knowledge. The studies in the literature examine these two aspects separately, thus the literature review of this study is divided into two sections. First, the studies that analyze ICT development levels using ICT indicators are presented. Second, the literature that focuses on ICT regulations in economies is reviewed.

There are different approaches in determining and measuring variables related to ICT since it is a multidimensional issue. For this reason, ICT can be measured by numerous indicators; and this leads to complexity for choosing the most appropriate indicator(s) among many. Moreover, when any topic has recently become important or new, it may take some time to determine the accurate indicators. The time lag occurs from both the necessity of representing indicators with accuracy and finding relevant historical datasets. Due to the mentioned structure of ICT, the topic is difficult to examine. Orlikowski and Iacano (2001) also underline this problem and emphasizes that the situation is not only limited to this topic but also valid for others such as technological innovation.

The studies that examine ICT by its indicators are Asongu and Nwachukwu (2019), Latapu et al. (2018), Gorkey-Aydinoglu and Yalki-Berker (2016) Emrouznejad et al. (2010), and Baliamoune-Lutz (2003). These studies choose different indicators by their

focus on the matter. Asongu and Nwachukwu (2019) analyze the effect of openness of ICT on governance in sub-Saharan Africa by selecting mobile phone and internet penetration rates as ICT indicators. Latapu et al. (2018) make research to determine the level of the digital divide and factors affecting access to ICT in Tonga. For this purpose; telephones, television, computers, and the internet are used to represent ICT. Gorkey-Aydinoglu and Yalki-Berker (2016) examine the development of ICT in BRICS economies from 2005 to 2013 by using four indicators. These indicators are fixed-broadband subscriptions, fixed-telephone subscriptions, mobile-cellular-telephone subscriptions, and the percentage of individuals using the internet. Emrouznejad et al. (2010) aim to develop an alternative approach for measuring ICT, as ICT has many aspects and various indicators. They include four sub-indices and ten indicators to identify ICT in their study. They are; main telephone lines, mobile cellular subscribers, and international internet bandwidth for network sub-indices; adult literacy rates and gross enrolment rates for skills sub-indices; internet users, the proportion of households with a television, and a computer for uptake sub-indices; and total broadband internet subscribers, international outgoing telephone traffic for the intensity sub-indices to identify ICT. Another study on the matter is Baliamoune-Lutz (2003); which analyzes the relationship between ICT diffusion and per capita income, trade and financial indicators, education, and freedom indicators. Internet hosts, internet users, personal computers, and mobile phones are selected as indicators of ICT in this study.

The literature lacks a precise agreement about choosing an accurate indicator(s) among many. Moreover, some of the ICT indicators have become obsolete following the emergence of new technologies. Accordingly, the most significant problem on the matter can be regarded as the selection of appropriate indicators that can accurately express the ICT level of an economy. This problem is also evidenced in studies that focus on certain aspects of ICT. However, the ICT development index, which includes 14 indicators, was developed by International Telecommunication Union (ITU) in 2008 and it has also been updating according to changing trends over the years (ITU, 2019a). Even though some studies are not related to the ICT development index, they also face difficulties while selecting accurate indicators from several of them. The first contribution of this study on the literature is that it takes into account the most recent indicators, which quantify the usage, access, and infrastructure, to classify ICT development levels in economies.

The literature is not rich in studies that specifically focus on ICT regulation. The main studies are Jorgenson and Vu (2016), Garcia-Murillo and MacInnes (2003), and Ulrich and Chacko (2005). Jorgenson and Vu (2016) emphasize the necessity of ICT for economic growth and the importance of the policies on the issue. It also provides a detailed ICT pol-

icy framework and dimensions. For ICT legal and regulatory framework dimension focus areas are mentioned as telecommunications regulation, spectrum frequency allocation, e-commerce laws, cybersecurity laws and regulations, ICT trade tariff and regulations, access to data and cross-border data transfer, and investment regulations. The latter part of this study does not explain the relevant matters in detail but mentioned the importance of those briefly. Garcia-Murillo and MacInnes (2003) evaluate ICT regulations from a different perspective. First, the study addressed that ICT regulation is usually more common in economies with greater competition and this results in new services occurrence and changes in the structure of the industry. Since ICT has various dimensions, related regulations also differ. For this reason, it becomes more complicated to balance the power and control within the policymakers. At last, the study points out the challenges in the implementation of the regulations and their advantages and disadvantages. Ulrich and Chacko (2005) criticize the role of governments in ICT policies. They emphasize that solely designing policy does not create any effect without taking action about it. Additionally, it clearly states the economic, social, cultural differences among countries; and points out that policymakers must consider these factors so that the policies can succeed. All these studies emphasize the importance of the existence of regulations from different points of view. None of these directly focus on the regulations, but only a part of the studies are about ICT regulation. Since regulations have become a necessary dimension for ICT, Information Telecommunication Union (ITU) has recently published different reports about the subject. The most detailed report related to regulations is "Global ICT Regulatory Outlook 2018" which gives information about countries' ICT regulations; but more importantly, it measures their regulation level (ITU, 2018). Since these reports are very recent; regulation related studies for ICT do not take place in the literature as needed. Thus, this is the second literature gap that this study aims to fill in. The ultimate aim of this study is to link two separate aspects, the regulatory aspect and the development aspect, and examine whether the levels of ICT regulations in action are in line with the ICT development levels in economies.

3. Methodology and Data

3.1 Theoretical Background: Hierarchical Clustering Methodology

The clustering methodology serves as a statistical data organization technique. It is used to classify heterogeneous objects (units) into homogeneous groups, which are referred to as clusters. If n is the number of objects, p is the number of variables; clustering approach groups n objects into clusters by taking into account the variables to calculate a dissimilarity (or similarity) matrix. The objects within the clusters are expected to possess similarity – homogeneity -, whereas the objects between clusters are expected to have dissimilarity – heterogeneity (Quah and Crowley, 2010; Ozdamar, 1999).

Dissimilarity and similarity are expressed by matrices. Theoretical background is provided as follows: $D \equiv (d_{ij})$ is dissimilarity matrix, and S $\equiv (s_{ij})$ is similarity matrix; where i and j are objects (countries), and $i = j = (1, \dots \dots, n)$

Dissimilarity matrix theoretically fits the following conditions (Gordon, 1996):

i. $d_{ij} \geq 0$,
ii. $d_{ii} = 0$,
iii. $d_{ij} = d_{ji}, \quad i = j = 1, \dots, n$

Most frequently used dissimilarity measures are Euclidean distance (*d(i,j)*), and squared Euclidean distance ($d(i,j)^2$). The formulae of Euclidean distance and squared Euclidean distance are shown in Equations (1) and (2), respectively.

$$d(i,j) = \sqrt{\sum_{k=1}^{p}(X_{ik} - X_{jk})^2} \qquad (1)$$

$$d(i,j)^2 = \sum_{k=1}^{p}(X_{ik} - X_{jk})^2 \qquad (2)$$

where $i = j = 1, \dots, n$ and $k = 1, \dots, p$. n denotes objects, and p denotes variables (Ozdamar, 1999).

Hierarchical clustering (HC) is one of the most frequently used types of clustering methodology, and it creates clusters by merging or dividing objects using a similarity matrix. Dividing is applied by taking all objects in one cluster in the first step. At the next iteration, one of the objects is separated to constitute a separate cluster. The iterations continue until all objects form their separate clusters. The analysis ends with n number of separate clusters. This type of HC is called divisive HC. Merging is applied by taking each ob-

ject as a different cluster so that the analysis starts with n number of clusters. At the next iteration, one of the objects joins another object, and they constitute a cluster together. The iterations repeat until all objects are merged in one cluster. This type of HC is referred to as agglomerative HC. At the end of the analysis, there is only one cluster that includes all the objects. Since HC, both divisive and agglomerative HC, clearly shows the convergence process of the objects, it holds an advantage as a clustering methodology. Another advantage of HC is that it is effectively used in large datasets, and large clusters (Abbas, 2008; Quah and Crowley, 2010).

Agglomerative HC has many algorithms, and each is different from the others by their way of merging clusters. Constituting one of these algorithms, Ward's linkage method starts the merging process from n number of clusters. Each cluster is combined with another one at each step to reach only one cluster, with all the objects in it. In this method, clusters are merged by minimizing variance within clusters. It uses the following formula to measure dissimilarities between clusters:

$$d_{mj} = ((N_j + N_k)d_{kj} + (N_j + N_l)d_{lj} - N_j d_{kl})/(N_j + N_m) \quad (3)$$

where*; j, k, l,* and *m* denote clusters (Ozdamar, 1999; Ward, 1963).

The first iteration of the cluster merging process applied by Ward's method is presented as follows: $U = \{e_1, e_2, e_3, \ldots, e_n\}$ includes n number of one-element clusters. Two of these clusters are combined as follows:

$$[S(1,n)] \cup [S(1,n)] = \{e_1, e_2\} \quad (4)$$

where *S* denotes clusters. The iterations are completed when all clusters are merged into one cluster (Ward, 1963). An optimal number of clusters can be determined either by the dendrogram diagram or the pseudo-F index (Quah and Crowley, 2010).

In this study; objects (n) are countries, and variables (p) are ICT indicators. As it covers a cross-section of 137 economies and includes seven ICT indicators: n=137, and p=7.

3.2. Data

The Global Information Technology Report, published by WEF (2016) covers almost all indicators related to ICT. According to this report, ICT indicators were first divided into 4 main sub-indexes: denominated environment, readiness, usage, and impact sub-indexes. Then, more specific indicators took part in each of these sub-indexes. As this study clusters

countries in terms of their ICT development; the indicators that have indirect effects on the matter are not included in the study; such as skills, economic and social impacts. Therefore, the study focuses on individual usage, access, and infrastructure factors, which constitute the core indicators of the subject. Hence, indicators of this study are selected from the most recent indicators available in the dataset for 137 economies in 2014 or 2015. These indicators are individuals using the internet, households with a personal computer, households with internet access at home, mobile broadband subscriptions, international internet bandwidth, mobile network coverage, and secure internet servers.

Individuals using the internet *(USG)* shows the percentage of individuals who used the internet in that year. Households with a personal computer *(HPC)* is presented as the percentage of the households who own a computer. A computer does not include any other types of equipment other than a personal computer, a laptop, or a desktop. The proportion is found by dividing the number of households who own a computer by the total number of households. Households with internet access at home *(ACC)* indicates the percentage of households who have internet access at home. At least one household member has to be between the ages 15-74 for this indicator. The percentage is calculated by the same calculation method with the households with a personal computer indicator. Mobile broadband subscriptions *(MBS)* refers to the actual subscribers per 100 population. It includes the total number of standard mobile broadband and dedicated mobile broadband subscriptions to the public internet. These four indicators represent the individual usage and access factors with the most recent version. According to the ITU (2019a), some indicators such as fixed-telephone subscriptions, mobile-cellular telephone subscriptions, and fixed-broadband subscriptions dropped due to the lack of representation of the usage and access factors. For this reason, these indicators are eliminated in this study.

International internet bandwidth *(IBW)* refers to the total capacity of all internet traffic which is measured in kb/s. Mobile network coverage *(COV)* shows the percentage of the population within the scope of a mobile cellular signal. The percentage is found by calculating the proportion between the population within the scope of a mobile cellular signal and the total population. Secure internet servers *(SEC)* means the internet servers which have encryption technology and this indicator's values are measured as per million population. These three indicators represent the infrastructure factor of ICT. As the total seven indicators show, they are all directly associated with the development level of ICT (ITU, 2019a).

The analysis includes 137 countries whose data can be accessed to these 7 indicators from the WEF (2016), and the descriptive statistics are presented in Table 1. Table 1 also

includes the descriptive statistics for the country classifications based on their development levels according to the UN M49 (ITU, 2019c; UN, 2019). Table 1 shows that 93 economies are classified as developing economies among 137 economies. It also obviously presents that, developed economies have larger values for all ICT indicators, as expected.

Table 1: Descriptive statistics, ICT indicators

			USG	HPC	ACC	MBS	IBW	COV	SEC
All Countries	n=137	Mean	48.84	47.14	45.36	46.08	152.83	93.97	342.02
		Median	49.30	51.10	46.60	42.10	33.70	99.00	40.90
		St.Dev.	28.74	31.30	31.37	35.43	672.83	14.36	651.63
		Min	1.40	0.10	0.10	0.00	0.10	1.90	0.10
		Max	98.20	98.10	98.50	141.70	6887.70	100.00	3214.40
Developed Countries	n=44	Mean	76.18	76.76	75.39	69.99	325.40	99.46	886.30
		Median	77.95	80.15	78.20	66.35	114.60	99.80	665.85
		St.Dev.	14.22	15.39	15.86	28.53	1031.60	0.90	865.56
		Min	43.40	23.50	26.60	7.50	11.50	95.00	23.80
		Max	98.20	98.10	97.50	138.50	6887.70	100.00	3214.40
Developing Countries	n=93	Mean	35.91	33.12	31.15	34.77	71.19	91.37	84.51
		Median	37.40	26.90	24.60	28.10	16.40	98.00	11.40
		St.Dev.	24.50	26.82	26.48	32.75	388.38	16.83	262.36
		Min	1.40	0.10	0.10	0.00	0.10	1.90	0.10
		Max	91.50	97.20	98.50	141.70	3721.80	100.00	2178.30

Source: WEF (2016). *Authors' calculations.*

The other dimension of the study is to compare the ICT levels of the countries and their ICT regulations in force. For this purpose, the ICT Regulatory Tracker, designed by ITU (2019b), is selected for the regulation indicator.

The ICT Regulatory Tracker has a unique measurement procedure. It contains 50 indicators and these indicators are classified into four main groups that are; regulatory authority, regulatory mandates, regulatory regime, and competition framework. Each group has a specific score and there is a limitation for the highest scores which cannot be exceeded. Based on this scoring system, each country has an ICT regulation score over a hundred, and it represents the countries' generations of the regulation level. The ICT Regulatory Tracker does not consider the effectiveness or implementation level in countries. It solely concerns their existence. G1 is the lowest level with a score of between 0 and 39. This level means

that the relevant industry was managed, controlled, and regulated by public monopolies. The score of G2 is between 40 and 69. In this level, there is liberalization and privatization; and another important factor is that open markets take place at this generation level. The G3 level indicates that the country has a high ICT regulation score, between 70 and 84. Thus, these countries have regulations on issues such as investment, innovation, competition, and consumer protection. G4 is the highest level of generations of regulations with a score between 85 and 100. At this level, the countries have integrated regulations, which are related to both economic and social policy goals. The explanation of regulation levels of G1, G2, G3, and G4 is summarized as regulated public monopolies, basic reform, enabling competition, and integrated regulation, respectively (ITU, 2018).

This study solely uses the regulation score and generations of the ICT regulatory tracker. An examination of the sub-indicators of the four main groups is not considered separately, as it is beyond the limits of the study.

4. Empirical Results

4.1. Empirical Findings from the Hierarchical Clustering Analysis

The study first classifies economies into clusters using seven ICT indicators mentioned in the Data section of the study. The hierarchical cluster approach is applied by using Ward's method and taking squared Euclidean distance as a measure. All the indicators are ranged between -1 and 1 to suppress unit differences across them (Ozdamar, 1999; Ward, 1963).

According to the dendrogram diagram of hierarchical clustering analysis, five clusters are selected as the optimal number of clusters. Even though Mali, Gabon, and Burundi formed a sixth cluster; an examination of the data shows that the ICT indicators in these three economies are close to those in the first cluster. Based on this closeness and of the fact that the number of economies in the sixth cluster is too low – only three -, these three economies are included in the first cluster for practical purposes. The dendrogram diagram is presented in Appendix A. Findings from three to seven clusters are also presented in Appendix B, to present the change in economies' classifications as the number of clusters change.

Table 2 presents the total of 137 economies included in the analysis and their distribution among five clusters.

Clusters are ordered and named depending on the development level of countries according to the selected indicators. A higher cluster number indicates a higher development

level in ICT. Therefore, Cluster 5 includes the countries with the highest ICT development level, whereas Cluster 1 indicates countries with the lowest ICT development level. Descriptive statistics of the ICT indicators by five clusters are presented in Appendix C.

Table 2 shows that the cluster which includes a larger number of countries is Cluster 1. The findings of the cluster analysis show that; despite the well-known and rising importance of ICT, 40 countries among 137 countries still had extremely low indicators in 2015. Appendix C indicates how mean, median, minimum and maximum values of each indicator are lower in Cluster 1, compared to those in others. Most of these economies are classified as least developed countries by the UN (2019), and they are mostly in Africa, and in Asia and the Pacific region (ITU, 2019c).

Table 2: Statistical findings, 5 clusters for 137 countries, 2014 or 2015

Clusters	Countries	n
Cluster 1	Algeria, Bangladesh, Benin, Botswana, Burundi, Cambodia, Cameroon, Chad, Cote d'Ivoire, El Salvador, Eswatini, Ethiopia, Gabon, the Gambia, Guatemala, Guinea, Haiti, Honduras, India, Indonesia, Lao PDR, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Myanmar, Namibia, Nepal, Nicaragua, Pakistan, Rwanda, Senegal, Sri Lanka, Tanzania, Uganda, Zambia, Zimbabwe	40
Cluster 2	Albania, Bhutan, Bolivia, Cape Verde, Dominican Republic, Ecuador, Egypt, Ghana, Guyana, Jamaica, Kenya, Kyrgyz Republic, Mexico, Mongolia, Nigeria, Paraguay, Peru, Philippines, South Africa, Thailand, Tunisia, Vietnam	22
Cluster 3	Argentina, Armenia, Azerbaijan, Bosnia and Herzegovina, Brazil, Bulgaria, Chile, China, Colombia, Costa Rica, Georgia, Greece, Iran, Islamic Rep., Jordan, Kazakhstan, N. Macedonia, Malaysia, Mauritius, Moldova, Montenegro, Morocco, Panama, Portugal, Romania, Serbia, Seychelles, Trinidad and Tobago, Turkey, Ukraine, Uruguay, Venezuela	31
Cluster 4	Belgium, Croatia, Cyprus, Czech Republic, France, Hungary, Ireland, Israel, Italy, Latvia, Lebanon, Lithuania, Oman, Poland, Qatar, the Russian Federation, Saudi Arabia, Slovak Republic, Slovenia, Spain	20
Cluster 5	Australia, Austria, Bahrain, Canada, Denmark, Estonia, Finland, Germany, Hong Kong, Iceland, Japan, Korea Rep., Kuwait, Luxembourg, Malta, Netherlands, New Zealand, Norway, Singapore, Sweden, Switzerland, United Arab Emirates, United Kingdom, United States	24

Clusters 2 and 3 in Table 2 mostly consist of emerging markets and developing economies; and Cluster 4 and 5 include advanced economies, such as G7 economies and the European economies, according to the IMF (2019), as expected. Even though empirical findings from the cluster analysis are in parallel to the country development classifications, it indicates some exceptions. Two of the exceptions are Greece and Portugal. Even though they are classified as advanced economies by the IMF (2019); according to the findings of the cluster analysis, they are grouped in Cluster 3 which generally includes emerging markets and developing economies. Another exception is that some economies are empirically grouped in the same cluster with advanced economies (Clusters 4 and 5), however, they are classified as emerging markets and developing economies according to the IMF (2019). These economies are Lebanon, Oman, Russian Federation, Saudi Arabia, Bahrain, Kuwait, and United Arab Emirates. Despite these exceptions, Table 2 shows parallel classifications in terms of overall development and ICT development levels.

4.2. The Comparison of Clusters and Regulations in Force

Table 3 presents a comparison between ICT development levels and ICT regulations in force in 2015. It classifies 137 economies into clusters, which were empirically generated by the hierarchical cluster approach, and presents ICT regulation levels for each economy. Score columns show ICT regulation score, and generation (G) columns indicate ICT generation. A higher regulation score is expected to be associated with a higher ICT development; as the purpose of any regulation is to organize and manage industry and to overcome any existing issues (ITU, 2018). Thus, the findings from Table 3 aim to explore whether ICT regulations in force are sufficient to provide development in ICT.

Cluster 1 in Table 3 consists of economies with the lowest ICT level, according to the findings of the cluster approach. The ICT regulations and legislations in force in these economies are mostly grouped in G2, some of them were grouped in G3, and only a few are grouped in G1. A remarkable situation in this cluster is the existence of economies with G4 level of ICT regulation: Botswana, Tanzania, Pakistan, and Uganda. Despite the availability of great numbers of regulations, these economies lagged behind many in terms of ICT development in 2015.

The result of the empirical findings shows that Clusters 2 mostly include emerging and developing economies. The existence of ICT regulations and legislations in these countries are mostly grouped in G2 and G3. There is only one economy, Bolivia, with an ICT regulation level of G1. The exceptions for this group are economies with G4, the highest, level

of generations. Although Peru's, Ghana's, Kenya's, Mexico's, and Dominican Republic's ICT regulations in force are grouped in G4, which is the highest generation; these economies are classified in Cluster 2. The findings clearly show that; despite the existence of numerous regulations and legislations, these economies were not able to reach a higher ICT development level in 2015.

Cluster 3 indicates economies with a moderate level of ICT development. This cluster includes economies with ICT regulation of G2, G3, and G4. Hence, this cluster can be regarded as heterogeneous in terms of the regulatory framework. All the economies with ICT regulation of G4 need to be particularly mentioned for this cluster, as a high level of regulations in these economies can only ensure a moderate level of ICT development. Specifically, Turkey, Montenegro, and Portugal require further examination, as they have even higher ICT regulation scores (higher than 90), compared to the others. Since this study aims to investigate whether the existence of ICT regulations and ICT development levels show parallelism with each other, the findings from cluster 3 are crucial. Even though all clusters show some exceptions, the exceptions in cluster 3 are much higher in number. Many economies classified in cluster 3 have a moderate level of ICT development despite many regulations in action. The findings may be interpreted as these regulations are not sufficient to make these economies reach a stronger ICT usage, access, and/or infrastructure.

Cluster 4 includes economies with a high level of ICT development. These economies mostly had a great number of ICT regulations in force, as their scores correspond to the G4 level. Hence, the exceptions for this cluster arise if the economies have lower ICT regulation scores. Only a few exceptions are available in this cluster. They are the Russian Federation and Lebanon with ICT regulation of G1, and Israel, and Qatar with ICT regulation of G2. Even though these economies had a high ICT development level, they lacked a sufficient amount of ICT regulations and legislations. These economies indicate interesting cases, as they were successful to reach a higher ICT usage, access, and infrastructure with quite low regulations in action.

Table 3: The comparison of ICT development and ICT regulations in force by clusters, 137 countries, 2015

	Countries	Score	G	Countries	Score	G	Countries	Score	G
Cluster 1	Eswatini	27.00	G1	Ethiopia	27.00	G1	Lao PDR	35.67	G1
	Myanmar	39.83	G1	Chad	40.33	G2	Guatemala	47.17	G2
	Haiti	53.83	G2	Burundi	56.00	G2	Liberia	56.33	G2
	Mozambique	57.67	G2	Madagascar	59.00	G2	Gabon	59.50	G2
	Benin	60.00	G2	Algeria	60.50	G2	Cote d'Ivoire	61.83	G2
	Lesotho	61.83	G2	Indonesia	62.00	G2	Mauritania	62.00	G2
	Sri Lanka	62.33	G2	Cameroon	64.00	G2	Guinea	66.33	G2
	Mali	67.00	G2	Cambodia	67.33	G2	Namibia	67.67	G2
	Zambia	67.67	G2	Nepal	68.00	G2	Zimbabwe	71.00	G3
	Bangladesh	71.50	G3	India	71.50	G3	El Salvador	73.50	G3
	The Gambia	73.67	G3	Nicaragua	74.00	G3	Rwanda	75.33	G3
	Senegal	77.67	G3	Malawi	78.67	G3	Honduras	82.00	G3
	Botswana	85.00	G4	Tanzania	85.00	G4	Pakistan	86.00	G4
	Uganda	86.00	G4						
Cluster 2	Bolivia	34.50	G1	Philippines	47.67	G2	Guyana	50.50	G2
	Bhutan	59.17	G2	Paraguay	60.83	G2	Vietnam	62.00	G2
	Mongolia	67.00	G2	South Africa	67.67	G2	Tunisia	70.33	G3
	Kyrgyz Rep.	72.50	G3	Jamaica	75.5	G3	Albania	77.00	G3
	Nigeria	78.33	G3	Cape Verde	79	G3	Egypt	79.83	G3
	Thailand	79.83	G3	Ecuador	83.5	G3	Peru	87.00	G4
	Ghana	87.33	G4	Kenya	87.5	G4	Mexico	90.00	G4
	Dominican Rep.	92.50	G4						
Cluster 3	China	49.00	G2	Kazakhstan	54.00	G2	Seychelles	54.00	G2
	Azerbaijan	60.17	G2	Uruguay	67.00	G2	Ukraine	67.67	G2
	Iran	71.67	G3	Colombia	74.50	G3	Mauritius	75.83	G3
	Jordan	78.00	G3	Chile	79.00	G3	Armenia	79.50	G3
	Venezuela	80.50	G3	Panama	82.50	G3	Moldova	83.50	G3
	Costa Rica	84.00	G3	N. Macedonia	84.00	G3	Trin.&Tob.	84.83	G3
	Serbia	85.50	G4	Argentina	86.00	G4	Bosnia&Herz.	86.00	G4
	Malaysia	86.00	G4	Romania	86.00	G4	Georgia	86.50	G4
	Greece	88.33	G4	Brazil	88.5	G4	Morocco	88.5	G4
	Bulgaria	89.17	G4	Turkey	91.83	G4	Montenegro	92	G4
	Portugal	92.00	G4						
Cluster 4	Russian Fed.	22.5	G1	Lebanon	31.67	G1	Israel	66	G2
	Qatar	66.17	G2	Saudi Arabia	85	G4	Latvia*	85.5	G4
	Cyprus	85.67	G4	Spain	86	G4	Czechia	87	G4
	Slovak Rep.	87.17	G4	Oman	87.33	G4	Poland	90.5	G4
	Belgium	92	G4	Hungary	92.5	G4	Slovenia	92.5	G4
	France	93	G4	Croatia	94	G4	Lithuania	95	G4
	Italy	95.33	G4	Ireland	97	G4			
Cluster 5	Kuwait	17.33	G1	Japan	70	G3	New Zealand	73	G3
	UAE	76.5	G3	Korea Rep.	81.67	G3	Hong Kong	82.83	G3
	Luxembourg	83	G3	Netherlands	83.5	G3	Estonia	85	G4
	Canada	85.5	G4	Iceland	86	G4	US	86.5	G4
	Sweden	87	G4	Bahrain	87.33	G4	Denmark	87.67	G4
	Singapore	88.5	G4	Austria	89.5	G4	Finland	92	G4
	Malta	92	G4	Switzerland	92	G4	UK	92	G4
	Germany	93.5	G4	Norway	94	G4	Australia	94.5	G4

Source: ITU (2019b). Clusters were determined using the hierarchical clustering approach.

* 2014 for Latvia. ICT regulation scores for Latvia were above 85 (G4), both in 2014 and 2016. Only in 2015, the score was 84.5 (G3). Since 2015 can be regarded as an exception, Latvia's indicator presents 2014 values.

Notes: Score refers to the ICT regulation score. G refers to ICT regulation generation 0<G1<39, 40<G2<69, 70<G3<84, 85<G4<100. G1=regulated public monopolies, G2= basic reform, G3=enabling competition, and G4=integrated regulation (ITU, 2018).

Cluster 5 indicates the countries with the highest ICT development level among 137 countries included in the study. Most of these countries are rich in ICT regulation, and hence most are grouped in G4, as expected. A remarkable exception for this cluster is Kuwait, with a score of only 17, and is grouped in G1. Despite the existence of small numbers of regulations and legislations in Kuwait, the country is clustered with the countries that have the highest ICT development level in the analysis. Aside from Kuwait, this cluster signals only a little heterogeneity, as only a small number of economies are grouped in the G3 level of regulations. From this perspective, not only Kuwait but also the economies with the G3 level of regulation needs a particular examination. Specifically, Japan, New Zealand, and UAE require further investigation among economies, since they have even lower regulation scores (lower than 80) compared to the others with the G3 level of regulations.

Considering the comparison of ICT regulations and ICT development levels by all clusters, Table 3 points out that the existence of a regulatory framework does not always guarantee that an economy will development level in terms of ICT. Thus, the research answers the research question as follows: The existence of ICT regulations in force are not directly, but partially in line with the development of ICT.

Table 4: Descriptive statistics for ICT regulation score, by clusters, 137 countries, 2015

Clusters	n	Mean	Median	Std. Dev.	Min.	Max.
Cluster 1	40	63.72	65.17	14.80	27.00	86.00
Cluster 2	22	72.25	76.25	14.99	34.50	92.50
Cluster 3	31	79.23	84.00	11.76	49.00	92.00
Cluster 4	20	81.59	87.25	20.44	22.50	97.00
Cluster 5	24	83.37	86.75	15.42	17.33	94.50

Source: ITU (2019b). *Authors' calculations.*

Table 4 presents descriptive statistics for ICT regulation scores by clusters, and it shows that; as the ICT development level - cluster number - rises, the mean and median scores rise. However, it does not reflect a similar trend for the minimum and maximum scores. The minimum scores are the lowest in Cluster 5, and 4, and the maximum score is the highest in Cluster 4. In addition to this, standard deviations of the scores for all clusters are high, especially in Cluster 4 and 5. Taking into account the heterogeneity, the descriptive statistics in Table 4 confirm the findings from Table 3 that answers the research question of this study as regulatory framework and development in ICT are partially in line in 2015 for the countries examined in this study.

The study finds out partial parallelism for the following reasons. Some economies may have a stronger ICT system with higher access, usage, and infrastructure basis despite lower regulations; whereas some may be weaker in ICT development despite the existence of numerous numbers of regulations. The former may be associated with a higher technological adoption which signifies that the society can readily accept and embrace new technology easily. The latter may arise when there are regulations in force only as written, yet not being applied in practice. Another reason may occur if existing regulations aim to limit the access, usage, and spread of technological knowledge or ICT. The reasons for these exceptions may be different from each other for economies, and they require further research to determine country-specific explanation. Even though this study aims to determine these exceptions, it does not aim to explain country-specific reasons and such explanations are out of the scope of this study.

5. Conclusion

The rising importance of the ICT industry in economies examines the matter necessary from different perspectives from various aspects. As the first attempt to connect two important aspects of ICT: regulatory framework and development, this study aims to answer the following research question: Are the regulations in force in line with the development of ICT? The topic can be analyzed by its indicators; however, the existence of numerous indicators makes such examination complicated. Thus, by focusing on the most recent indicators accepted by ITU (2019a), this study first classifies 137 economies depending on their ICT development level by using hierarchical clustering methodology in 2015. After that, the findings of the cluster analysis are compared with the existence of regulations in force in those economies.

The empirical findings of the cluster analysis indicate that the optimal number of clusters is five, meaning that these economies can be statistically classified into five clusters. Each cluster consists of countries with a similar ICT development level. The empirical findings show that countries in each cluster are also mostly similar in terms of economic development, according to the country classifications of the IMF (2019) and the UN (2019). Thus, the classification of countries for ICT development and economic development are mostly consistent with each other, except for a few exceptions.

Even though, economic development levels of economies are consistent with their cluster distribution, as the empirical findings indicated; this consistency is not much apparent for ICT regulation and development levels. Even though some parallelism between ICT regulation and ICT development exists; exceptions, which signal extreme cases, are appar-

ent within clusters. This partial inconsistency is also confirmed by the descriptive statistics of the regulation scores. Accordingly, the findings of the study answer the research question as follows: The regulations in force were only partially in force with the development of ICT in 137 economies examined in 2015.

The comparison of the findings from the cluster analysis, and the ICT regulation tracker shows that; the regulation levels are diversified in each cluster. The countries in Clusters 1 and 2 mostly include economies with low regulation scores. Even though Botswana, Tanzania, Pakistan, Uganda, Peru, Ghana, Kenya, Mexico, and the Dominican Republic have an extremely high regulation score, they were classified in these clusters, which mostly include countries with low ICT development level. These contrarieties make it necessary to examine the coverage of the regulations in these economies. The regulations in force were either ineffective, or they might have been designed to serve as barriers to access to and usage of ICT. From these perspectives, country-specific analyses are particularly necessary for these countries for further research. The ICT regulation structure of countries in Cluster 3 is heterogeneous; as the cluster consists of different ICT regulation generations, such as basic reform phase (G2), enabling competition (G3), and integrated regulation (G4). Countries with a regulation level of G4 require a particular examination in this cluster. Despite numerous ICT regulations and legislations; they were incapable of reaching a higher ICT development level. From this perspective; this study underlines the importance of further research also for these economies; particularly for Turkey, Montenegro, and Portugal, as the regulation scores of these economies are remarkably higher. The examination of Clusters 4, and 5 shows a contrast, compared to the first three clusters. The exceptions in the previous clusters are related to lower or moderate ICT development, yet a great number of ICT regulations. Since Clusters 4 and 5 imply high ICT development, the exceptions in these clusters point out an insufficient amount of ICT regulations. These economies are the Russian Federation, Lebanon, Israel, Qatar, and Kuwait. Even though there were only little regulations in these economies, they were successfully developed in ICT.

Further research can be directed to regional or country-specific studies; particularly to country-specific empirical studies for the mentioned economies. Such empirical studies may contribute to the literature by first determining the reasons for regulation-development mismatch in ICT, and then by making necessary policy proposals for increasing ICT usage, access, and infrastructure with the help of appropriate country-specific policies.

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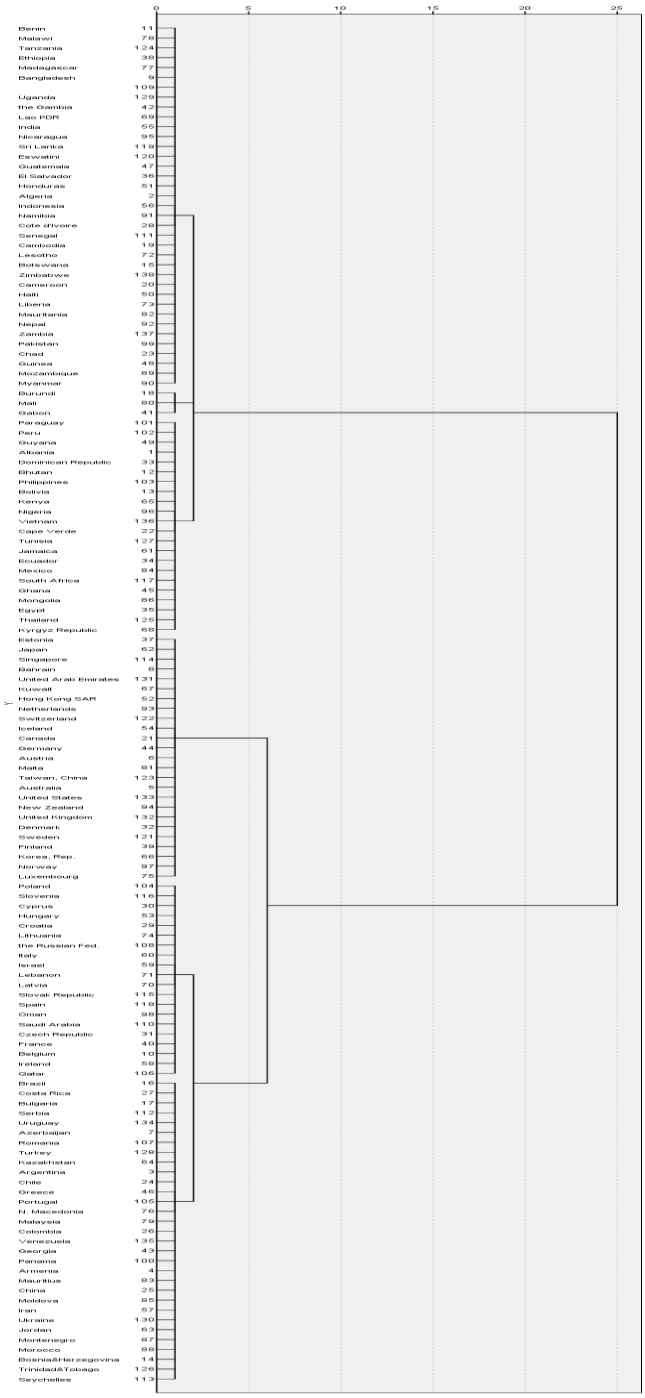
Appendix A. Dendrogram Diagram of Hierarchical Clustering Analysis

Figure 1: Dendrogram using Ward linkage



Appendix B. Empirical Findings of Hierarchical Clustering Method. 3, 4, 5, 6, and 7 Clusters.

Table B.1.: Empirical findings of the Hierarchical Clustering Method, from 3 to 7 clusters

Countries	3 Clusters	4 Clusters	5 Clusters	6 Clusters	7 Clusters
Algeria	1	1	1	2	2
Bangladesh	1	1	1	2	2
Benin	1	1	1	2	2
Botswana	1	1	1	2	2
Burundi	1	1	1	1	1
Cambodia	1	1	1	2	2
Cameroon	1	1	1	2	2
Chad	1	1	1	2	2
Cote d'Ivoire	1	1	1	2	2
El Salvador	1	1	1	2	2
Eswatini	1	1	1	2	2
Ethiopia	1	1	1	2	2
Gabon	1	1	1	1	1
Gambia, The	1	1	1	2	2
Guatemala	1	1	1	2	2
Guinea	1	1	1	2	2
Haiti	1	1	1	2	2
Honduras	1	1	1	2	2
India	1	1	1	2	2
Indonesia	1	1	1	2	2
Lao PDR	1	1	1	2	2
Lesotho	1	1	1	2	2
Liberia	1	1	1	2	2
Madagascar	1	1	1	2	2
Malawi	1	1	1	2	2
Mali	1	1	1	1	1
Mauritania	1	1	1	2	2
Mozambique	1	1	1	2	2
Myanmar	1	1	1	2	2
Namibia	1	1	1	2	2
Nepal	1	1	1	2	2
Nicaragua	1	1	1	2	2
Pakistan	1	1	1	2	2

Countries	3 Clusters	4 Clusters	5 Clusters	6 Clusters	7 Clusters
Rwanda	1	1	1	2	2
Senegal	1	1	1	2	2
Sri Lanka	1	1	1	2	2
Tanzania	1	1	1	2	2
Uganda	1	1	1	2	2
Zambia	1	1	1	2	2
Zimbabwe	1	1	1	2	2
Albania	1	2	2	3	3
Bhutan	1	2	2	3	3
Bolivia	1	2	2	3	3
Cape Verde	1	2	2	3	3
Dominican Republic	1	2	2	3	3
Ecuador	1	2	2	3	3
Egypt	1	2	2	3	3
Ghana	1	2	2	3	3
Guyana	1	2	2	3	3
Jamaica	1	2	2	3	3
Kenya	1	2	2	3	3
Kyrgyz Republic	1	2	2	3	3
Mexico	1	2	2	3	3
Mongolia	1	2	2	3	3
Nigeria	1	2	2	3	3
Paraguay	1	2	2	3	3
Peru	1	2	2	3	3
Philippines	1	2	2	3	3
South Africa	1	2	2	3	3
Thailand	1	2	2	3	3
Tunisia	1	2	2	3	3
Vietnam	1	2	2	3	3
Argentina	2	3	3	4	4
Armenia	2	3	3	4	4
Azerbaijan	2	3	3	4	4
Bosnia and Herzegovi	2	3	3	4	4
Brazil	2	3	3	4	4
Bulgaria	2	3	3	4	4

Countries	3 Clusters	4 Clusters	5 Clusters	6 Clusters	7 Clusters
Chile	2	3	3	4	4
China	2	3	3	4	4
Colombia	2	3	3	4	4
Costa Rica	2	3	3	4	4
Georgia	2	3	3	4	4
Greece	2	3	3	4	4
Iran, Islamic Rep.	2	3	3	4	4
Jordan	2	3	3	4	4
Kazakhstan	2	3	3	4	4
Macedonia, FYR	2	3	3	4	4
Malaysia	2	3	3	4	4
Mauritius	2	3	3	4	4
Moldova	2	3	3	4	4
Montenegro	2	3	3	4	4
Morocco	2	3	3	4	4
Panama	2	3	3	4	4
Portugal	2	3	3	4	4
Romania	2	3	3	4	4
Serbia	2	3	3	4	4
Seychelles	2	3	3	4	4
Trinidad and Tobago	2	3	3	4	4
Turkey	2	3	3	4	4
Ukraine	2	3	3	4	4
Uruguay	2	3	3	4	4
Venezuela	2	3	3	4	4
Belgium	2	3	4	5	5
Croatia	2	3	4	5	5
Cyprus	2	3	4	5	5
Czech Republic	2	3	4	5	5
France	2	3	4	5	5
Hungary	2	3	4	5	5
Ireland	2	3	4	5	5
Israel	2	3	4	5	5
Italy	2	3	4	5	5
Latvia	2	3	4	5	5
Lebanon	2	3	4	5	5
Lithuania	2	3	4	5	5

Countries	3 Clusters	4 Clusters	5 Clusters	6 Clusters	7 Clusters
Oman	2	3	4	5	5
Poland	2	3	4	5	5
Qatar	2	3	4	5	5
Russian Federation	2	3	4	5	5
Saudi Arabia	2	3	4	5	5
Slovak Republic	2	3	4	5	5
Slovenia	2	3	4	5	5
Spain	2	3	4	5	5
Australia	3	4	5	6	7
Austria	3	4	5	6	7
Bahrain	3	4	5	6	6
Canada	3	4	5	6	7
Denmark	3	4	5	6	7
Estonia	3	4	5	6	6
Finland	3	4	5	6	7
Germany	3	4	5	6	7
Hong Kong SAR	3	4	5	6	6
Iceland	3	4	5	6	7
Japan	3	4	5	6	6
Korea, Rep.	3	4	5	6	7
Kuwait	3	4	5	6	6
Luxembourg	3	4	5	6	7
Malta	3	4	5	6	7
Netherlands	3	4	5	6	7
New Zealand	3	4	5	6	7
Norway	3	4	5	6	7
Singapore	3	4	5	6	6
Sweden	3	4	5	6	7
Switzerland	3	4	5	6	7
United Arab Emirates	3	4	5	6	6
United Kingdom	3	4	5	6	7
United States	3	4	5	6	7

Note: The countries are ordered according to the statistical findings for 5 clusters, which was selected as the number of clusters for the analysis.

Appendix C. Descriptive Statistics of ICT Indicators by Clusters

Clusters were generated by the hierarchical clustering approach.

Table C.1.: Descriptive statistics of ICT indicators, by clusters

		USG	HPC	ACC	MBS	IBW	COV	SEC
Cluster 1	Mean	12.68	9.90	9.34	12.76	10.36	83.56	4.96
	Median	12.60	8.20	6.50	8.70	5.90	92.45	2.50
	Std. Dev.	7.33	6.69	6.88	12.15	11.30	22.89	5.74
	Minimum	1.40	0.10	0.10	0.00	0.10	1.90	0.10
	Maximum	29.70	28.20	29.10	49.70	50.30	100.00	22.50
Cluster 2	Mean	40.09	28.84	25.35	35.53	28.93	96.11	25.19
	Median	40.40	32.05	26.00	30.95	20.80	98.75	20.60
	Std. Dev.	8.80	9.13	7.52	20.64	33.35	6.89	24.80
	Minimum	18.90	9.10	8.50	0.20	2.50	70.00	2.30
	Maximum	60.10	45.10	37.30	79.90	149.50	100.00	115.60
Cluster 3	Mean	55.19	55.83	52.48	42.91	59.46	98.06	86.14
	Median	54.90	52.50	52.00	44.00	44.50	99.50	56.30
	Std. Dev.	8.57	8.42	8.44	19.33	47.38	3.20	92.32
	Minimum	39.40	38.20	34.20	7.50	5.00	86.60	2.10
	Maximum	72.40	70.10	68.30	87.20	218.90	100.00	469.80
Cluster 4	Mean	74.43	78.66	77.13	63.42	93.36	99.37	370.71
	Median	73.40	79.15	74.95	64.60	91.45	99.80	308.80
	Std. Dev.	7.37	6.53	8.53	14.52	65.25	1.12	252.81
	Minimum	62.00	68.10	66.00	34.00	11.50	95.00	45.90
	Maximum	91.50	97.20	98.00	99.00	263.90	100.00	854.20
Cluster 5	Mean	87.61	88.47	88.08	100.96	674.03	99.58	1500.83
	Median	87.25	87.85	89.55	106.55	174.95	99.95	1384.30
	Std. Dev.	6.60	5.89	6.51	25.80	1523.46	0.70	813.93
	Minimum	73.20	78.30	75.40	54.30	28.70	97.00	177.00
	Maximum	98.20	98.10	98.50	141.70	6887.70	100.00	3214.40

Notes: USG is the percentage of individuals using the internet, HPC is the percentage of households with a personal computer, ACC is the percentage of households with internet access at home, MBS is mobile broadband subscriptions per 100 population, IBW is international internet bandwidth kilobytes per user, COV is mobile network coverage per 100 population, and SEC is secure internet servers per million population.