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A Conceptual Model and Methodology for Evaluating E-Infrastructure Deployment and Its Application to OECD and MENA Countries

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A Conceptual Model and Methodology for Evaluating E-Infrastructure Deployment and Its Application to OECD and MENA Countries

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Abstract: As information and communication technologies have spread throughout the world, countries have realized the importance of investing more and more in building ICT-relevant infrastructure. However, for fostering further information and communication technology (ICT) development, countries are in need of an analysis tool for measuring their advancement in ICT-relevant infrastructure. Motivated by a variety of attempts to generate measures of ICT development, this study aims to develop an index that quantifies the level of ICT-relevant (e-infrastructure) deployment. In particular, this study introduces two e-infrastructure indices that are composed of six components, namely electricity, telecommunication, Internet, processing power, broadcasting, and human capital. Each component is generated from one or more indicators. This composition provides the possibility of tracking each of them separately and to identify strengths and weaknesses of each country with respect to the ICT-relevant area of the component. It will also help pointing out the source of failure in developing the ICT-related infrastructure and to develop policies for enhancing ICT-related infrastructure accordingly. For the index computation, the study uses a parametric and a non-parametric computation method rather than the traditional approaches which are frequently used in literature. In addition to this, this study also aims at analyzing the indices ranking differences among OECD countries and Middle East & North Africa (MENA) countries, using data for the time period between 2000 and 2007. The ranking of the countries shows that MENA and OECD countries differ significantly in their e-infrastructure development. However, a small group of MENA countries are ranked higher than a few OECD countries. Those countries belong to the Gulf Cooperation Council (GCC).

Keywords: ICT Infrastructure, Indices, e-Readiness, Composite Index, Principle Component Analysis, MENA, OECD.

JEL Classification Numbers: C01, C14, C22, C43, C51, L86, L96, R58.

1. Introduction

The rapid rate of Internet and mobile diffusion throughout the world, together with dramatic advances in the uses of information and communication technologies (ICT) in business, industry, and public administration has resulted in the introduction of many Internet-based services such as e-business, e-commerce, e-government, and e-learning. However, the provision of such services in a country mainly depends on the level of its existing ICT-relevant infrastructure (e-infrastructure). It is clear that an appropriate level of e-infrastructures needs to be in place, in order to have businesses and citizens of a country benefit from the ICT deployment.

To date, a vast number of ICT rankings between countries have been formulated by researchers, governments, and private institutions. Some of them are the Technological Achievement Index (TAI), the Networked Readiness Index (NRI), the Digital Access Index (DAI), the Digital Opportunity Index (DOI), and the ITU ICT Development Index (IDI). Despite these significant efforts and the importance of these indices for measuring e-readiness, the e-infrastructure, which is considered to be the basis for such development has not been investigated much. These indices are still unable to fully identify the true extent of e-infrastructure development as their indicators do not reflect the level of the countries' readiness in terms of e-infrastructure.

This study introduces two new e-infrastructure indices that quantify the level of e-infrastructure deployment in a country. The two e-infrastructure indices that we have developed in this study cover not only ICT access and use but also all infrastructure areas that are related to ICT development. The indices comprise six components: electricity, telecommunication, Internet, processing power, broadcasting, and human capital. Each of those components is generated from a comprehensive coverage of related indicators that are prerequisites for subsequent access and usage of information and telecommunication technologies. The two e-infrastructure indices differ in the computation method applied. One index uses a parametric method and the other a non-parametric method.

Apart from the design of the two e-infrastructure indices, the contribution of the paper is the ranking of OECD countries and Middle East & North Africa (MENA) countries according to the two indices. The results show that the majority of OECD countries are ranked higher than MENA countries. The MENA countries, which belong to the Gulf Cooperation Council (GCC), can outperform a few OECD countries.

The remainder of the paper is organized as follows: First, a literature review about existing ICT development indices are presented in section two. The framework of the two new e-infrastructure indices is presented in section three. While section four describes the data and variables used in the analysis of the study, section five introduces the methodologies used in the computation of the e-infrastructure index. Section six describes the results of the empirical analysis. Finally, the conclusion of the study is given in section seven.

2. Literature Review

E-readiness assessments are meant to guide development efforts by providing benchmarks for comparison and gauging progress [1]. In most cases, e-readiness is represented in terms of indices, where countries are measured in various areas such as

the number of telephone lines per 100 people, or the percentage of GDP spent on IT infrastructure. The results are tabulated and can then be used to make comparisons both between countries in the term of rankings, as well as longitudinal studies within countries [2]. E-readiness indices are mainly constructed for ranking countries such that their differences in the access to ICT can be measured. Given the importance of the e-readiness assessment, several organizations, academia, and researchers have suggested different definitions and tools. The Economist Intelligence Unit defines e-readiness as the measure of a country's ability to use digital channels for communication, commerce, and government, in order to foster economic and social development [3]. Asian Pacific Economic Cooperation (APEC) defines e-readiness as the degree to which an economy or community is prepared to participate in the digital economy [4]. CID's[1] readiness for the networked world defines a framework for developing countries to evaluate their e-readiness [5]. It defines the readiness as "the degree to which a community is prepared to participate in the network world", which is measured by addressing a community's relative advancement in the areas that are most critical for ICT adoption and most important for ICT applications. [2] defines e-readiness as a measure of the degree to which a country or economy may be ready, willing, or prepared to obtain the benefits of information and communication technologies.

2.1. Existing ICT Development Indices

A vast number of ICT rankings between countries have been prepared by many public, private, and multi-lateral institutions. The ranking systems differ in terms of data gathering, methodologies, and definitions of the e-readiness concept. As a result, findings from different institutions may differ from each other. Each assessment tool or model has a different underlying goal and definition of e-readiness. Some of the organizations that have been on the forefront in developing e-readiness assessment tools include (but are not limited to) the Networked Readiness Index (NRI), the Technology Achievement Index (TAI), the New Indicator of Technological Capabilities (ArCO), the Economist Intelligence Unit (EIU) E-Readiness Ranking Tool, the UNCTAD ICT Development Index, the Digital Access Index (DAI), the Digital Opportunity Index (DOI), the ICT Opportunity Index (ICT-OI), the ITU ICT Development Index (IDI), and the Telecommunication and Broadcasting Infrastructure Index [6][7][8][9][10][11][12][13]. Although these indices are developed to measure and rank the e-readiness of countries, they have been developed from different perspectives. As a result, some findings seem to be inconsistent with each other.

2.2. Shortcoming of the existing indices

Despite the significant efforts and importance of the above indices for measuring ICT development, the e-infrastructure, which is considered as the basis for such development is not investigated much. For instance, the most relevant index to this study is the IDI that have been developed by ITU. However, the IDI excludes infrastructure supply (such as electricity) and does not take into consideration

[1] CID refers to Harvard University's Center for International Development

technology convergence of telecommunication and broadcasting, and the emergence of new technologies and services, such as IPTV, digital terrestrial TV and WiMAX, which can use one or both kinds of infrastructures. Another related piece of work has been developed by Adnan et al. [13]. It focused on telecommunications and broadcasting infrastructure but excludes the electricity infrastructure. Moreover, most of the existing indices include other factors rather than e-infrastructure factors, which might show the real state of the ICT-related infrastructure.

The e-infrastructure index that we developed in this study is the first to cover all areas of infrastructure required for ICT development. It focuses on measuring the e-infrastructure level with comprehensive coverage of the related indicators. The framework and indicators used for the construction of the e-infrastructure index will be discussed in more detail in the next section.

3. Conceptual Framework for Developing the E-Infrastructure Index

3.1. Main Objectives and Conceptual Framework

At the outset, it is necessary to define the main objectives of the index, i.e., to answer the question what exactly should be measured. Therefore, as the main objective of this study is to develop an index reflecting the level of technological infrastructure in a country (e-infrastructure Index), the provisioning of measures for existing e-infrastructures of developing countries, especially MENA countries, is important. Then, those countries can be benchmarked with developed countries in the OECD.

The framework for the construction of the e-infrastructure index departs from the basic assumption that any country can be ready to implement any kind of e-services once its e-infrastructure is in place. For example, as the adoption of e-government and e-commerce mainly depends on the level of existing technology-relevant infrastructures, these infrastructures should be in place beforehand. Without that, there will be hardly e-government and e-commerce-related development. Therefore, the index should give an indication of the extent to which a country has advanced in all technology-related infrastructure areas and provide a holistic picture on the state of technology-related developments within the country.

3.2. Selection of Indicators for Constructing the E-Infrastructure Index

Based on the above described framework, the selected indicators should correspond to the following six components of the index (or sub-indices): electricity, telecommunications, Internet, processing power, broadcasting, and human capital. For each sub-index a list of potential indicators will be established. The selection of the indicators was based on the availability of the data (and their quality) for developing countries. Since ICT data availability in the majority of developing countries is poor, this was the main restrictive factor in the selection. The selection, however, restricts only the relevance of a particular indicator for contributing to the main objectives and conceptual framework of the index. In the following section, the indicators for each sub-index of the index will be presented.

4. Data and Variables

The main data was obtained from the Word Development Indicator database 2009, ITU- World Telecommunication/ICT Indicators 2009, and the UNESCO Institute for Statistics (UIS), covering 20 countries of MENA (Middle East and North Africa) and 27 countries of the OECD (Organization for Economic Cooperation and Development) for the time period 2000 to 2007.

The electric power consumption per capita (kilowatt per hour per capita) indicator will be used as a proxy measure for the electricity sub-index. Lack of electricity and problems with existing telecommunication infrastructure are some of the problems faced specially by developing countries with regard to ICT development. The telecommunication sub-index is composite of fixed telephone lines per 100 inhabitants and mobile cellular telephone subscriptions per 100 inhabitants. As mobile cellular telephony is increasingly replacing fixed telephony in many countries, it is a key indicator for measuring telephone access and uptake. However, despite the high growth of mobile subscriptions and their role in replacing fixed telephony in developing countries, fixed lines remain essential for both voice traffic as well as a basis for upgrading to broadband infrastructure.

The Internet quality and connectivity is a vital infrastructure for any country in terms of its ICT development. The Internet sub-index is based on a composite of Internet users per 100 inhabitants and the international Internet bandwidth per inhabitant (bits/second/inhabitant). The Internet users indicator is able to measure the uptake of Internet access by a country. The international Internet bandwidth refers to the capacity that backbone operators provide to carry Internet traffic. It is measured in bits per second. The international Internet bandwidth per inhabitant is calculated by dividing the amount of bandwidth (in bits/second) by the total population [14]

The processing power sub-index concerns the computer access and supercomputing in those countries. For this sub-index, we suggest two indicators: personal computers (PCs) per 100 inhabitants and the number of Supercomputers. However, due to the lack of data about the supercomputers, only the indicator of personal computers per 100 inhabitants was used for the computation of the processing power sub-index.

Recently, broadcasting along with telecommunication infrastructure is becoming well-known, as a result of conversions of services. The indicator used for this sub-index is the television sets per 100 inhabitants. Also, cable television subscribers per household and satellite indicators can be used in this sub-index. However, as mentioned above, the selection of indicators takes into account the availability of data in the countries under study.

For the human capital sub-index, the key considerations are the human capital component, which captures the level of engineers and technicians required to install, operate, and maintain ICT, as well as the ICT skills in a country. Despite the availability of simple ICT devices such mobile devices requiring little reading skills, use of the Internet requires a fairly complex set of skills and technological know-how. Moreover, in most cases, it requires a reasonable fluency in English. There are five indicators in this sub-index, the first three are for skills and the last two are for the engineers and technicians. The indicators are: primary school enrollment (% gross amount); secondary school enrollment (percent gross amount); tertiary school

enrollment (% gross amount); technicians per million inhabitants and science and engineering enrollment ratios. Due to the lack of data availability in the countries under study, we had to exclude the last two indicators. Therefore, the computation of the human capital sub-index is based only on the first three indicators.

5. Methodology and Model Specification

An e-infrastructure index that is multi-dimensional and decomposable will be a useful tool in the quantification of the extent and evaluation of the level of ICT-related infrastructure. The methodology used includes two different methods. The first method computes the e-infrastructure index non-parametrically, based on the normalized Human Development Index (HDI) type index. The second method estimates the e-infrastructure index parametrically, using the principal component analysis (PCA). The reason for selecting the two methods is to allow for a more detailed analysis by comparing both outcomes.

5.1. Non-Parametric E-infrastructure Index

The non-parametric index is a composite index constructed to aggregate a number of indicators of a certain outcome [15]. Such indices are used for measuring many economic or social phenomena, such as globalization [16] [17][18][19][20], the state of the environment [21] human development [22], and the trajectory of development strategy, technology and research [23][7].

The basic of our non-parametric index is the very commonly used index, the United Nation Human Development Program (UNDP) Human Development Index (HDI). However, we used a different method of weighting rather than the traditional approach of equal weighting, which is frequently used in other literature in the construction of such non-parametric indices. The weights of our e-infrastructure index were given based on the square of their normalized values. By using this system of weighting we can see the difference in the performance of countries which are ranked at the top. This is because the countries that have high values are given higher weights. The non-parametric e-infrastructure index is then computed as subsequent aggregation of its components as follows:

$$npindex_{ct} = \sum_{j=1}^{J}\left\{\frac{1}{M}\sum_{m=1}^{M}\left\{\left(x_{jmct} - x_{jmt}^{\min}\right)/\left(x_{jmt}^{\max} - x_{jmt}^{\min}\right)\right\}\right\}^{2} \qquad (1)$$

where c and t indicate the country and the time period. m is the individual indicator for each j component. X_{ct} is the observed value of the individual indicator m in a given year. $X_t^{\min}$ is the minimum and $X_t^{\max}$ is the maximum values of the indicator across countries in a given year, allowing for year-specific reference points.

5.2. Parametric E-infrastructure Index

Beside the non-parametric index, this study also adopts a parametric method for computing an e-infrastructure index, using principal component analysis (PCA). PCA

is a multivariate technique for reducing multidimensional data sets to lower dimensions. In short, this method gives a least square solution to the following model:

$$Y_{it} = \sum_{j=1}^{J} \beta_j X_{jit} + E_{it} \qquad (2)$$

where Xj (j=1,2,….J) are factor scores. βj is the factor pattern or eigenvector. E_{it} is the residual. Unlike the traditional lease squares estimation case, in which the vertical distance to the fitted line is minimized, the PCA minimizes the sum of the squared residuals measured as distances from the point to the principal axis[24][25].

Traditionally, researchers, who use the principal component analysis methodology, use the first principal component to arrive at a single "omnibus" measurement scale. In this study, however, we use a more elaborated approach. We rely on the weighted average of several principal components with Eigenvalues greater than 1.0, in order to utilize all the power in explaining variations in the data. In the aggregation, the share of variance explained by each component is used as weights.

6. Empirical Results and Analysis

Summary statistics of the variables are given in Table 1. We observed large variations among the variables that are used for calculating the index. The distribution of the index components is also not uniform. This is particularly evident for the component electricity, Internet, computer, and broadcasting. It has a large dispersion and has a sample mean higher than the median. In case of the human capital component, the mean and median values almost overlap.

Table 1. Summary statistics of e-infrastructure data, 2000-2007, 376 observations.

Variable	N	Mean	Median	Std Dev	Minimum	Maximum
region	376	2.8723	3	1.105	1	4
year	376	2003.5	2003.5	2.2943	2000	2007
elec	376	7540.4	6398.2	6305.2	135.58	36853
fixd	376	35.844	42.031	20.866	1.227	74.867
cell	376	64.859	72.309	38.244	0	176.5
intn	376	33.753	29.058	25.831	0.048	86
comp	376	30.714	23.966	25.642	0.195	101.47
band	376	23821	817.91	386755	0.179	8.00E+06
tvse	376	51.675	48.917	33.237	6.443	308.38
prim	376	101.15	101.6	11.69	32.5	128
seco	376	94.571	95.9	24.446	13.7	161.7
tert	376	45.84	49.75	23.602	0.3	94.9

Abbreviations: *elec (electricity consumption per capita (kwh per capita, kilo Watt hour per capita)), fixd (fixed telephone lines per 100 inhabitants), cell (mobile subscribers per 100 inhabitants), intn (Internet users per 100 people), comp (personal computers per 100 inhabitants), band (international Internet bandwidth per inhabitant (bits/sec)), tvst (number of TV sets per 100 inhabitants), prim (primary school enrollment (percent gross)), seco (secondary school enrollment (percent gross)), tert (tertiary school enrollment (percent gross))*

6.1. Estimation of the e-Infrastructure Indices and their Components

6.1.1. Non-Parametric e-Infrastructure Index

Using equation (1), the non-parametric e-infrastructure is computed based on the normalization of the 10 individual indicators and the subsequent aggregation using the square value of the sub-indices of the index.

Table 2. Country's ranking by non-parametric e-infrastructure index for 2007.

	Country	Region	year	elect	phone	comp	inter	media	human	npindex
1	Norway	Europe	2007	0.457	0.388	0.428	0.252	1.000	0.513	3.038
2	Iceland	Others	2007	1.000	0.593	0.337	0.156	0.019	0.484	2.588
3	Luxembourg	Europe	2007	0.193	0.662	0.508	0.918	0.032	0.203	2.517
4	Sweden	Europe	2007	0.168	0.596	0.836	0.224	0.089	0.450	2.364
5	Netherlands	Europe	2007	0.035	0.442	0.911	0.249	0.095	0.505	2.236
6	Canada	Others	2007	0.210	0.336	1.000	0.185	0.058	0.437	2.225
7	Switzerland	Europe	2007	0.047	0.643	0.831	0.183	0.031	0.304	2.039
8	UK	Europe	2007	0.026	0.570	0.713	0.181	0.119	0.343	1.952
9	USA	Others	2007	0.134	0.388	0.657	0.182	0.097	0.472	1.931
10	Australia	Others	2007	0.091	0.404	0.564	0.100	0.038	0.713	1.909
11	Germany	Europe	2007	0.036	0.666	0.471	0.180	0.040	0.396	1.790
12	Denmark	Europe	2007	0.031	0.508	0.288	0.229	0.095	0.562	1.713
13	Finland	Europe	2007	0.214	0.318	0.276	0.217	0.046	0.595	1.666
14	France	Europe	2007	0.043	0.449	0.525	0.091	0.043	0.477	1.628
15	Ireland	Europe	2007	0.027	0.509	0.402	0.112	0.020	0.472	1.541
16	KoreaRep	Others	2007	0.051	0.353	0.318	0.201	0.014	0.602	1.540
17	NewZealand	Others	2007	0.066	0.351	0.306	0.169	0.036	0.583	1.511
18	Austria	Europe	2007	0.046	0.402	0.433	0.155	0.047	0.366	1.449
19	Italy	Europe	2007	0.023	0.561	0.221	0.101	0.054	0.462	1.422
20	Belgium	Europe	2007	0.053	0.381	0.202	0.156	0.031	0.457	1.279
21	Spain	Europe	2007	0.028	0.415	0.148	0.093	0.027	0.544	1.254
22	Japan	Others	2007	0.051	0.276	0.244	0.163	0.111	0.390	1.237
23	UAE	Mid.East	2007	0.190	0.541	0.125	0.091	0.001	0.254	1.202
24	Greece	Europe	2007	0.022	0.506	0.007	0.036	0.040	0.563	1.175
25	Bahrain	Mid.East	2007	0.145	0.379	0.031	0.037	0.013	0.418	1.023
26	Israel	Mid.East	2007	0.034	0.478	0.049	0.028	0.007	0.424	1.021
27	Portugal	Europe	2007	0.016	0.420	0.025	0.054	0.016	0.460	0.992
28	SlovakRep	Europe	2007	0.019	0.217	0.251	0.062	0.015	0.343	0.908
29	Qatar	Mid.East	2007	0.120	0.399	0.033	0.059	0.012	0.267	0.890
30	Hungary	Europe	2007	0.011	0.296	0.059	0.092	0.030	0.399	0.887
31	CzechRep	Europe	2007	0.029	0.286	0.108	0.082	0.017	0.361	0.883
32	Kuwait	Mid.East	2007	0.190	0.160	0.096	0.033	0.014	0.197	0.691
33	SaudiArabia	Mid.East	2007	0.037	0.187	0.018	0.021	0.005	0.294	0.563
34	Libya	N.Africa	2007	0.010	0.094	0.000	0.001	0.001	0.437	0.543
35	Iran	Mid.East	2007	0.003	0.123	0.008	0.011	0.001	0.305	0.451
36	Lebanon	Mid.East	2007	0.003	0.036	0.011	0.049	0.014	0.279	0.392
37	Jordan	Mid.East	2007	0.002	0.078	0.003	0.012	0.015	0.259	0.368
38	Tunisia	N.Africa	2007	0.001	0.083	0.004	0.009	0.003	0.260	0.359
39	Egypt	N.Africa	2007	0.001	0.041	0.001	0.006	0.004	0.285	0.338
40	Algeria	N.Africa	2007	0.000	0.078	0.000	0.003	0.002	0.255	0.338
41	Oman	Mid.East	2007	0.014	0.111	0.005	0.003	0.043	0.157	0.332
42	Syria	Mid.East	2007	0.001	0.038	0.006	0.010	0.002	0.262	0.318
43	Palestine	Mid.East	2007	0.001	0.015	0.002	0.003	0.001	0.228	0.250
44	Morocco	N.Africa	2007	0.000	0.047	0.000	0.014	0.001	0.131	0.195
45	Iraq	Mid.East	2007	0.001	0.022	0.056	0.000	0.009	0.104	0.190
46	Yemen	Mid.East	2007	0.000	0.003	0.000	0.000	0.017	0.064	0.084
47	Djibouti	N.Africa	2007	0.000	0.000	0.000	0.000	0.000	0.000	0.000

As shown in Table 2, the countries under study are ranked in descending order, based on the non-parametric index of 2007. Norway is ranked the highest followed by Iceland, Luxembourg, Sweden, and the Netherlands, which are ranked as 2nd, 3rd, 4th, and 5th, respectively.

The performance of countries differs by components and there is no condition that for a country to be the highest in one component, it must also have a high performance in other components. One such example is Norway which is ranked 1st. Although it has not the highest score in electricity (2nd), telecommunication (20th), computers (12th), Internet (2nd), or human capital (8th), it has the highest score in broadcasting media.

The highest/lowest contributing component to the country rank is for electricity Iceland/Djibouti, for telecommunication Germany/Djibouti, for computers Canada/Djibouti, for Internet Luxembourg/Djibouti, for broadcasting media Norway/Djibouti, and for human capital Australia/Djibouti.

Given the close relationship between e-infrastructure and GDP, MENA countries, in particular those that are least developed such as Iraq, Yemen and Djibouti, rank at the bottom of the e-infrastructure index (45th, 46th and 47th, respectively).

6.1.2. Parametric e-Infrastructure Index

The parametric e-infrastructure index is estimated using the Principal Component Analysis (PCA). PCA can reduce a large set of individual indicators to a small set, while preserving the maximum possible proportion of the total variation in the original data set. For the reduction purpose, it must be pointed out that the original variables should be correlated. If the original variables are uncorrelated, then PCA cannot reduce them to a small number of transformed variables and hence the analysis is of no value. Therefore, the first step is to check the correlation structure of the data and find out whether the indicators are correlated. The correlation coefficients among various index components are presented in Table 3.

Table 3. Correlation matrix.

	elec	fixd	cell	intn	Comp	band	tvse	prim	seco	tert
elec	1									
fixd	0.587	1								
cell	0.505	0.639	1							
intn	0.634	0.784	0.717	1						
comp	0.584	0.804	0.623	0.904	1					
band	0.073	0.052	0.117	0.100	0.094	1				
tvse	0.528	0.596	0.501	0.690	0.677	0.023	1			
prim	0.081	0.399	0.265	0.125	0.105	0.006	0.065	1		
seco	0.419	0.689	0.567	0.602	0.556	0.0116	0.492	0.459	1	
tert	0.413	0.716	0.545	0.711	0.617	-0.071	0.572	0.257	0.715	1

As expected, the various components are positively and mostly significantly correlated among themselves. Except for the coefficient value of the tertiary and bandwidth components, which shows a negative correlation (-0.0713), most indicators show positive correlation among themselves. The highest correlation (0.9048) is found between Internet users and personal computers. This is expected as accessing the Internet is highly dependent on the access to a computer. Similarly, there is a high correlation between fixed telephone lines and personal computers (0.8044). This is also expected as fixed telephone lines remain essential for dial-up (especially in developing countries) and DSL Internet connections.

As mentioned above, PCA involves also the extraction of the principal components. The results derived from PCA include Eigenvalues, the percent of variance explained in each component, and the total variance explained by all components. Those values are represented in Table 4.

Table 4. Eigenvalues of the correlation matrix.

No.	Eigenvalue	Difference	Proportion	Cumulative
1	**5.4765**	4.2909	0.5476	0.5476
2	**1.1856**	0.1621	0.1186	0.6662
3	**1.0235**	0.4671	0.1023	**0.7686**
4	0.5564		0.0556	0.8242

The next step is to identify the number of principal components that should be retained in the analysis without losing too much information. Using Kaiser's criterion (1960) for selecting the number of components, we dropped all components with Eigenvalues below 1.0. According to this rule, three principal components should be retained in the analysis of the e-infrastructure index.

As shown from the table above, the principal components with Eigenvalues greater than 1 are the first three. The first principal component explains the maximum variance in all the individual indicators (with an Eigenvalue of 5.4765). The second principal component explains the maximum amount of the remaining variance with an Eigenvalue of 1.1856 and the third principal components has an Eigenvalue of 1.0235. The proportion of total variance explained by these principal components is 0.5476 + 0.1186 + 0.1023 = 0.7686.

The Eigenvectors of each principal component are shown in Table 5. An Eigenvector value, which is larger than 0.3, indicates that an indicator has a significant contribution to the component. The sign indicates the direction of the contribution. Each indicator usually plays a significant role to only one principal component. As some indicators are repeatedly explained in two principal components, such as primary and secondary school enrollments, we use a weighted average index of the three principal components.

Table 5. Eigenvectors of the principal components.

	Prin1	Prin2	Prin3	Prin4
elec	0.3031	-0.206	-0.005	0.8309
fixd	0.3808	0.0068	-0.024	-0.096
cell	0.3333	0.0224	0.1516	0.1039
intn	0.3936	-0.179	-0.026	-0.089
comp	0.3759	-0.210	-0.035	-0.116
band	0.0327	-0.321	0.9014	-0.182
tvse	0.3245	-0.201	-0.156	-0.087
prim	0.1251	0.7599	0.3287	0.1849
seco	0.3372	0.3577	0.0583	-0.024
tert	0.3467	0.1787	-0.162	-0.439

In the computation of the parametric e-infrastructure index, the first three components are aggregated, using their share of variance as weight:

$$Prin123 = Prin1*(0.5476/0.7686) + Prin2*(0.1186/0.7686) + Prin3*(0.1023/0.7686) \quad (3)$$

The results based on the parametric method are reported in Table 6. Similar to the non-parametric index, the results show that OECD countries are ahead of the MENA countries with the exception of a few countries in the Gulf Cooperation Council (GCC). Bahrain, UAE, and Qatar are ranked ahead of several OECD countries. The index shows that Bahrain, which is considered as one of the fastest growing economies in the Middle East, leads all MENA countries in 2007.

The ranking based on the result of the parametric method shows Luxembourg, Norway, Australia, The Netherlands, and Iceland at the top of the list. This ranking of the top performers shows some slight differences to the ranking of the non-parametric e-infrastructure index. For example, Norway is ranked 2nd while it is ranked 1st according to the non-parametric e-infrastructure index. Luxembourg is first in the parametric e-infrastructure ranking and 3rd in the non-parametric e-infrastructure ranking. The highest difference in position is observed in case of Switzerland. It has been listed 7th in the non-parametric e-infrastructure index and 20th in the parametric e-infrastructure index.

Table 6. Parametric e-infrastructure index for 2007.

Rank	country	regionx	Prin1	Prin2	Prin3	Prin123
1	Luxembourg	Europe	1.276	-6.698	17.663	2.226
2	Norway	Europe	2.497	-2.216	-1.356	1.257
3	Australia	Others	1.308	0.675	0.046	1.042
4	Netherlands	Europe	1.466	-0.306	0.078	1.008
5	Iceland	Others	1.604	-1.058	-0.226	0.950
6	Sweden	Europe	1.618	-1.301	-0.483	0.888
7	Denmark	Europe	1.309	-0.257	-0.329	0.849
8	Finland	Europe	1.268	-0.483	-0.374	0.779
9	France	Europe	0.929	0.344	0.164	0.737
10	Germany	Europe	1.080	-0.260	0.046	0.735
11	NewZealand	Others	1.045	0.102	-0.189	0.735
12	USA	Others	1.321	-0.948	-0.608	0.714
13	Canada	Others	1.325	-1.083	-0.522	0.707
14	KoreaRep	Others	0.957	0.292	-0.176	0.704
15	UK	Europe	1.180	-0.865	-0.201	0.681
16	Ireland	Europe	0.865	0.242	0.138	0.672
17	Italy	Europe	0.885	0.159	0.106	0.669
18	Bahrain	MiddleEast	0.337	1.622	1.213	0.652
19	Spain	Europe	0.723	0.638	0.116	0.629
20	Switzerland	Europe	1.066	-0.987	-0.120	0.591
21	Belgium	Europe	0.781	0.035	0.018	0.564
22	Austria	Europe	0.853	-0.459	-0.004	0.536
23	Portugal	Europe	0.294	1.222	0.576	0.474
24	Japan	Others	0.818	-0.571	-0.392	0.443
25	Greece	Europe	0.523	0.598	-0.212	0.437
26	UAE	MiddleEast	0.446	-0.016	0.815	0.423
27	Israel	MiddleEast	0.252	0.898	0.457	0.379
28	Qatar	MiddleEast	0.201	0.406	0.811	0.313
29	CzechRep	Europe	0.281	0.030	0.165	0.227
30	Hungary	Europe	0.311	-0.124	-0.213	0.174
31	SlovakRep	Europe	0.203	0.002	0.148	0.165
32	SaudiArabia	MiddleEast	-0.289	0.724	0.636	-0.010
33	Kuwait	MiddleEast	-0.092	-0.581	0.241	-0.123
34	Libya	NorthAfrica	-0.585	1.383	0.385	-0.152
35	Iran	MiddleEast	-0.676	1.462	0.670	-0.167
36	Syria	MiddleEast	-0.958	1.631	0.859	-0.316
37	Tunisia	NorthAfrica	-0.765	0.667	0.386	-0.390
38	Algeria	NorthAfrica	-0.893	1.039	0.630	-0.392
39	Jordan	MiddleEast	-0.641	0.074	0.006	-0.444
40	Egypt	NorthAfrica	-0.860	0.720	0.195	-0.475
41	Lebanon	MiddleEast	-0.584	-0.161	-0.327	-0.485
42	Oman	MiddleEast	-0.618	-1.109	-0.380	-0.662
43	Morocco	NorthAfrica	-1.174	0.286	0.498	-0.726
44	Palestine	MiddleEast	-1.036	-0.558	-0.528	-0.894
45	Iraq	MiddleEast	-1.242	-0.391	0.099	-0.932
46	Yemen	MiddleEast	-1.558	-0.949	-0.284	-1.294
47	Djibouti	NorthAfrica	-2.137	-3.630	-1.343	-2.261

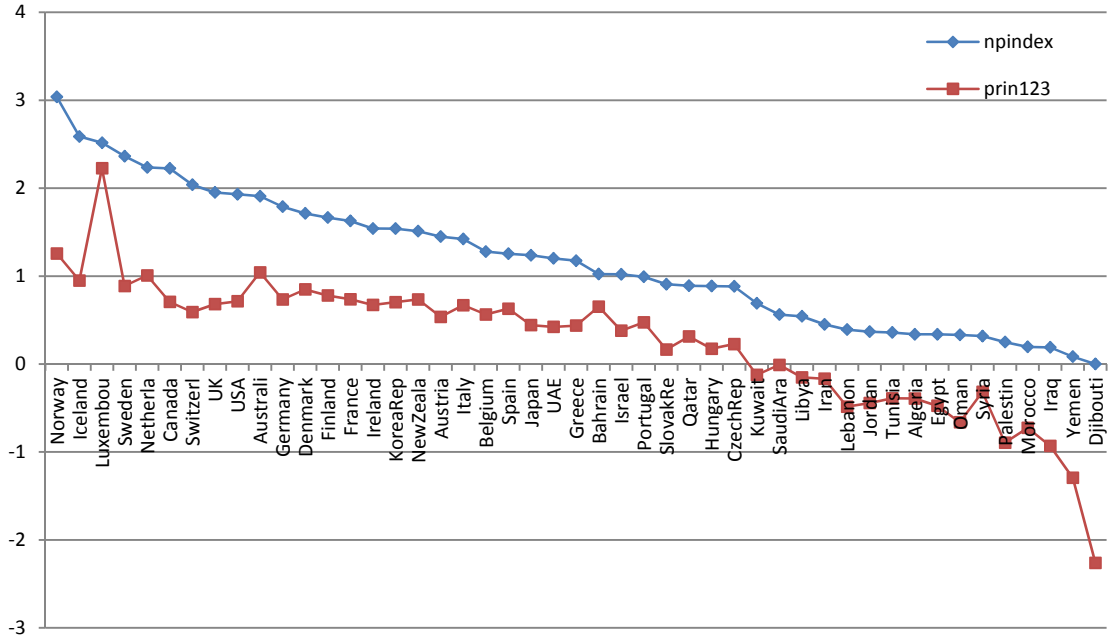


Figure 1. Comparison of non-parametric and parametric e-infrastructure indices for 2007.

Comparing the ranking of all countries according to both e-infrastructure indices in Figure 1, the overall result looks similar though. The differences in ranking of each country is little as well as the variation of ranking positions. The parametric e-infrastructure index (npindex) is sorted in descending order, providing homogeneously distributed values. It results in almost a linear curve. The non-parametric e-infrastructure index provides very similar values for a large portion of countries, which are ranked in the middle of the list. Irregular differences between the two indices are observed in two cases, Djibouti and Luxembourg

In addition to this, both rankings show that the low rank of some countries is to some extent linked to their economic condition. On the one hand, poor countries from MENA have low ranks. On the other hand, rich countries, which belong to the Gulf Cooperation Council (GCC) and have made remarkable developments, are ranked higher than many OECD countries.

7. Conclusion

In this study, we developed and presented two composite indices that quantify the level of e-infrastructure of a country. The e-infrastructure indices are composed of six main components: electricity, telecommunication, Internet, processing power, broadcasting, and human capital. Each component is composed of one or more indicators. We have also suggested several improvements for the composition of the index.

The first index is the non-parametric e-infrastructure index. It is based on the normalized human development index. Unlike human development index based indices, in which weights are assigned on an ad-hoc basis, our index components were given weights based on the square of their normalized values. The second index is the

parametric e-infrastructure index. The weights of this index are estimated using the principal component analysis.

Despite the different methods in the index computation, the outcome of the indices differs only slightly. For example, the country ranking based on the e-infrastructure indices shows that the high-ranked countries share similar patterns in various index component distributions. For the majority of countries, their two ranks differ only slightly.

Besides, based on these two e-infrastructure indices, we analyzed the ranking of the countries, whereby we put a special focus on Middle East & North Africa (MENA) countries and OECD countries. The ranking also showed that some MENA countries, which belong to the Gulf Cooperation Council (GCC), outperformed a few OECD countries.

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