Chapter 8
Evaluation of E-Infrastructure Deployment in OECD and MENA Countries

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Abstract This paper introduces new indices quantifying country's level of e-infrastructure deployment. These indices comprise six components, which include several indicators, and are based on parametric or nonparametric methods. They improve existing indices. Based on index calculations, variations between countries, regions, and over time are analyzed. The data used covers MENA and OECD countries, 2000–2007. Analysis results identified areas, in which countries need improvements, and showed that some MENA countries outperformed some OECD countries. The rankings based on the indices differ only slightly. Additionally, the parametric method-based index produces equally distributed value ranges and shows an overall e-infrastructure improvement over time.

Keywords ICT infrastructure • Indices • E-readiness • Composite index • Principal component analysis • MENA • OECD

8.1 Introduction

The rapid proliferation of information and communication technologies (ICT) has resulted in the introduction of many Internet-based services such as e-business, e-commerce, e-government, and e-learning. As the provision of such services mainly

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depends on the level of the existing ICT-relevant infrastructure (e-infrastructure) in a country, it is clear that an appropriate level of e-infrastructures needs to be in place for a specific service to work successfully. E-infrastructure is the basis for ICT development. Only then, businesses and citizens of a country can benefit from ICT investments.

Despite this fact, e-infrastructure deployment has not been evaluated. Instead, a large number of indices for measuring ICT deployment in a country have been formulated by researchers, governments, and private institutions. These indices, which capture the ICT status, 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). The ICT-deployment indices are 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 new e-infrastructure indices that quantify the level of e-infrastructure development in a country. The e-infrastructure indices that we introduce cover not only ICT access and ICT use but also all infrastructure areas that are related to ICT development. The indices comprise the following six components: electricity, telecommunication, Internet, processing power, broadcasting, and human capital. Each of those components is generated from a comprehensive set of indicators that are prerequisites for subsequent access and use of information and telecommunication technologies. This composition also provides the possibility of tracking each of the components separately and, therefore, identifies strengths and weaknesses of a country with respect to the e-infrastructure-relevant area specified through the component. It will also help pointing out the source of failure in developing an e-infrastructure and in developing policies for enhancing an ICT-supporting infrastructure.

For the computations of the indices, which are based on parametric methods and nonparametric methods, this study also suggests several improvements for the composition of the indices compared to existing indices.

Furthermore, the paper calculates and analyzes the indices for different countries as well as the index variations between countries, regions, and over time. The data used for the analysis is about Middle East and North Africa (MENA) and OECD countries for the period between 2000 and 2007.

Moreover, the study also measures the efficiency of countries in terms of e-infrastructure development compared with the best practiced e-infrastructure country to show not only the rank but also the distance to the frontier country in e-infrastructure development.

The results show that countries differ significantly in their e-infrastructure development. We also observe some degree of heterogeneity by regional location. Although the majority of OECD countries are ranked higher than MENA countries, the MENA countries, which belong to the Gulf Cooperation Council (GCC), outperformed a few OECD countries.

Our results also show that the two e-infrastructure indices differ only slightly with respect to the results produced. However, the parametric method-based e-infrastructure index produces a more equally distributed value range and shows an expected evolution over the course of 7 years.

The remainder of the paper is organized as follows: First, in Sect. 8.2, a literature review about existing indices for measuring ICT deployment is presented and compared. The framework of the new e-infrastructure indices is given in Sect. 8.3. While Sect. 8.4 describes the data and indicators used in the analysis of the study, Sect. 8.5 introduces the methodologies used in the computation of the e-infrastructure indices. Section 8.6 describes the results of the empirical analysis. In Sect. 8.7, policy recommendations and a discussion on how to improve the e-infrastructure index are given. The paper concludes with a summary of the main findings of the study in Sect. 8.8.

8.2 Literature Review

E-readiness assessments are meant to guide development efforts, providing benchmarks for comparing and gauging the development progress of a country [29]. In many cases, e-readiness is given through indices, which measure various indicators (e.g., the number of telephone lines per 100 people and the percentage of GDP spent on information technology (IT)) that describe the country's situation in information technology. The results are tabulated and ranked. Then, the table can be used to make comparisons between countries and to conduct longitudinal studies for a single country [8]. The ranking of countries indicates the differences between countries.

8.2.1 Definition of Development Indices

Given the implications of the e-readiness assessment, several organizations, academia, and researchers are interested in this type of measure. However, it resulted in many different definitions of readiness. 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 [11]. Asia-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 [7]. It defines the readiness as "the degree to which a community is prepared to participate in the networked world," which measures a community's relative advancement in the areas that are most critical for ICT adoption and most important for ICT applications. Danish [8] defines e-readiness as a measure of the degree to which a country or economy is ready, willing, or prepared to obtain the benefits of information and communication technologies.

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

8.2.2 Existing ICT Development Indices

A large number of ICT rankings between countries have been prepared by many public and private institutions. The most known indices, on which the rankings are based, are 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), telecommunication and broadcasting infrastructure index (TI), and development of telecommunication infrastructure (DTI) suggested by Rudra et al. [30]. Archibugi et al. [6] compute nine internationally well-known technological capability composite indices using the same data and compare their correlation and performance in ranking countries. The indices are used to capture multidimensional nature of technological change and to rank countries based on different sets of indicators. The values of the indicators of technological capabilities are assessed for public policy, company strategies, and economic studies. Although these indices have been developed to measure and rank the e-readiness of countries, they have been developed from different perspectives, use different data, apply different methodologies, and define the e-readiness concept differently; the rankings and findings from different institutions differ from each other. Consequently, some findings seem to be inconsistent with each other. A comparison between these indices including their subindices, methodology, and usage is presented in Table 8.1.

8.2.3 Shortcomings of 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, has not been investigated much. For instance, the most relevant index to this study is the IDI, which has been developed by ITU. The IDI excludes infrastructure supply (e.g., electricity) and does not take into consideration technology convergence of telecommunication and broadcasting and the emergence of new technologies and services (e.g., IPTV, digital terrestrial TV, and WiMAX). Another related piece of work has been developed by Al-Mutawkkil et al. [1]. It focuses on telecommunications and broadcasting infrastructure but excludes the electricity infrastructure. Moreover, most of the existing indices include many factors that are not related to e-infrastructure and, therefore, do not show a realistic state of the ICT-related infrastructure. In another study Lim and Nguyen (2013) [25] compare the weighting schemes in the three traditional, principal component and dynamic factor approaches to summarizing information from a number of component variables and compare their performance. The results show the advantage of dynamic factor approach in capturing both significance and variability of the components.

Table 8.1 Comparison of existing ICT-related indices

Index name	Literature reference	Subindices	Methodology	Perspective/use
Technological achievement index (TAI), 2001/2002	UNDP [32], Desai et al. [9]	Creation of new technology	The methodology used to calculate the TAI is a simple average of the dimensions of the index, which in turn is calculated based on the selected indicators	TAI is a composite measure of technological progress that ranks countries on a comparative global scale
		Diffusion of newest technologies		
		Diffusion of oldest technologies		
		Human skills		
Networked readiness index (NRI), 2003	WEF, INSEAD & infoDev [33]	Environment for IT offered by a given country or community	135 variables were considered available from hard data and an executive opinion survey and narrowed these down to 65 based on a variety of criteria. These 65 variables were grouped into 11 separate micro-indices	It is defined as "the degree of reparation of a nation or community to participate in and benefit from IT developments"
		Readiness of the community's key stakeholders (individuals, businesses, and governments) to use IT		
		Actual use of IT among these stakeholders		
Indicator of technological capabilities (ArCO), 2004	Archibugi and Coco [5]	Creation of technology	The overall technology index (ArCo) has been built upon the equal weighting of the three mentioned categories	It is a more comprehensive indicator of technological capability
		Technological infrastructures		
		Development of human skills		
EIU E-readiness ranking tool, 2008/2009	Economist Intelligence Unit [11, 12]	Connectivity and technological infrastructure	In EIU 2009, over 100 separate criteria, both qualitative and quantitative, are evaluated for each country. The categories and the individual criteria within them (38 indicators and 81 sub-indicators) are weighted according to their assumed importance. The subindices are weighted as follows: connectivity and technology infrastructure 20%; business environment 15%; social and cultural environment 15%; legal environment 10%; government policy and vision 15%; consumer and business adoption 25%	It assessed the world's largest economies on their ability to absorb information and communications technology (ICT) and to use it for economic and social benefit
		Business environment		
		Social and cultural environment		
		Legal environment		
		Government policy and vision		
		Consumer and business adoption		

(continued)

Table 8.1 (continued)

Index name	Literature reference	Subindices	Methodology	Perspective/use
UNCTAD ICT development index, 2005	United Nations Conference on Trade and Development [31]	Connectivity	UNCTAD uses the aggregate index approach with component indices (similar to UNDP's HDI)	It assesses technological development
		Access		
		Policy		
		Usage of telecom traffic		
Digital access index (DAI), 2003	ITU [18]	Infrastructure (fixed telephone subscribers per 100 inhabitants and mobile phone subscribers per 100 inhabitants)	It is based on a methodology that uses goalposts (upper value limits), which were averaged to obtain category scores. Categories were then averaged to obtain the overall index value	It measures the overall ability of individuals in a country to access and use information and communication technologies
		Affordability		
		Knowledge		
		Quality		
		Usage		
ICT opportunity index (ICT-OI), 2007	ITU and Orbicom [20]	Networks	The ICT-OI calculates values for a reference country and reference year, which served as the basis for calculating changes in "infostate" developments	It was less designed as a tool for benchmarking and ranking countries, but rather for tracking country and group differences across time and in relation to each other
		Skills		
		Uptake		
		Intensity		
Digital opportunity index (DOI), 2005	ITU & United Nations Conference on Trade and Development [21]	Opportunity	The methodology used for the DOI was close to that of the DAI, using goalposts and absolute values	The objective of the DOI is to measure "digital opportunity" or the potential of countries to benefit from access to ICT
		Infrastructure		
		Utilization		

Index name	Literature reference	Subindices	Methodology	Perspective/use
ITU ICT development index (IDI), 2009	ITU [19]	ICT infrastructure and access	The IDI uses weighted summation applied to the normalized indicators and subindices	It tracks the digital divide and benchmarks information society developments
		ICT use		
		ICT skills		
Telecommunication and broadcasting infrastructure index (TI), 2009	Al-Mutawkkil et al. [1]	Telecommunications (fixed telephone, mobile phone, Internet)	The TI's three telecommunication infrastructure subindices are calculated using the parametric PCA approach, while the composite (TI) is calculated using nonparametric approach (weighted summation of the subindices)	It analyzes ICT-related infrastructures
		Broadcasting		
Technological capability indices (TCI), 2009	Archibugi et al. [6]	Review 9 indices: Tech WEF, TechRead WEF, TechInnov WEF, GSII EUComm, KIWB, ArCo, TAI UNCTAD, TechAdv UNIDO, and SII EUComm	Compute 9 internationally well-known technological capability composite indices using the same data and compare their correlation and performance in ranking sample countries	The indices are used to capture multidimensional nature of technological change and rank countries based on different sets of indicators. Assess the value of synthetic indicators of technological capabilities for public policy, company strategies, and economic studies

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Table 8.1 (continued)

Index name	Literature reference	Subindices	Methodology	Perspective/use
TR, PC, and DF indices, 2013	Lim and Nguyen [25]	Compare 3 performance indices: *TR*, traditional, *PC* principal component approach, and *DG* dynamic factor approach	Compare the weighting schemes in the three approaches to summarizing information from a number of component variables	The indices are used to capture multidimensional nature of technological change and rank countries based on different sets of indicators. Assess the value of synthetic indicators of technological capabilities for public policy, company strategies and, economic studies
DTI, 2014	Rudra et al. [30]	Examine the linkage between the development of telecommunication infrastructure (DTI), economic growth, and 4 indicator operations of a modern economy	Employ a panel vector-autoregressive model for detecting Granger causality	Find evidence of bidirectional Granger causality between DTI and economic growth in the long run

The e-infrastructure index that we present 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 related indicators. The framework and indicators used for calculating the e-infrastructure index will be discussed in more detail in the next section.

8.3 Conceptual Framework for Developing an E-Infrastructure Index

8.3.1 Main Objectives and Conceptual Framework

As the main objective of this study is to develop an index that reflects the level of information technological infrastructure in a country (e-infrastructure index), the provisioning of measures (i.e., indicators) for capturing the level of existing e-infrastructures of a country is the first step. Then, this index together with its indicators can be used by developed countries, as well as developing countries, to benchmark their performance. For example, it can be used by developing countries (e.g., by MENA countries as in our study) to compare their performance with developed countries in the OECD.

The framework for the construction of our 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 services mainly depends on specific, technology-relevant infrastructures (e.g., access to PCs that are connected to the Internet), these infrastructures should be in place before the introduction of e-government services. Without that, there will be neither hardly any use of e-government services nor further development of e-government services. Therefore, the index should give an indication of the extent to which a country has advanced in all IT-related infrastructure areas and provide a holistic picture of the state of IT-related developments within the country.

8.3.2 Selection of Indicators for the E-Infrastructure Index

In order to make an e-infrastructure index a useful tool for the quantification of the extent of the level of ICT-related infrastructure, we design our index to be multidimensional and decomposable [27]. Following the above-described framework, the selected indicators should represent all major areas of IT relevance. These six areas (which we will also call components or subindices) of the indices are (1) electricity, (2) telecommunications, (3) Internet, (4) processing power, (5) broadcasting, and (6) human capital. For each of these subindices, a list of potential indicators will be established. However, the selection of indicators was strongly influenced by the availability of data (and the quality of the data) for developing countries. Since the availability of IT-related data in the majority of developing countries is poor, data availability was the main restrictive factor in the selection. The selection impacts only the relevance of a particular indicator for contributing to the main objectives but not the conceptual framework of the e-infrastructure index.

8.4 Data and Indicators

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

The electric power consumption per capita (kilowatt per hour per capita) indicator is used as a proxy measure for the electricity subindex. The electricity subindex is important as the lack of electricity (besides problems with existing telecommunication infrastructure) which is one of the problems that developing countries face with regard to ICT development.

The telecommunication subindex is a composite of fixed telephone lines per 100 inhabitants indicator and the mobile cellular telephone subscriptions per 100 inhabitants indicator. As mobile cellular telephony replaces fixed telephony in many countries over time, the joined consideration of both indicators is important. The telecommunication subindex 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, fixed lines are a basis for Internet access and for upgrading to broadband Internet access.

The Internet is a vital infrastructure for any country in terms of its ICT development. The Internet subindex is based on a composite of the Internet users per 100 inhabitants indicator and the indicator of the Internet bandwidth of a country per inhabitant. While the first indicator (i.e., the Internet users indicator) measures the availability of Internet access by a country, the second indicator measures the quality of the Internet access. The Internet bandwidth of a country refers to the capacity that backbone operators provide to carry Internet traffic to and from other countries. The Internet bandwidth of a country per inhabitant (in bits/second/inhabitants) is calculated by dividing the amount of bandwidth (in bits/second) by the total population [17].

The processing power subindex concerns the computer access and supercomputing in those countries. For this subindex, we use two indicators: personal computers (PCs) per 100 inhabitants and the sum of the processing power of all supercomputers. However, due to the lack of data about supercomputers, only the indicator of personal computers per 100 inhabitants has been used for the computation of the processing power subindex.

Recently, as a result of convergence of services, Internet access and telecommunication services via broadcasting infrastructure become a common approach. To capture this, three indicators could be used for this subindex (media). The first indicator is the number of television sets per 100 inhabitants. The second and third indicators are the number of cable television subscribers per household indicator and the number of satellite subscribers per household indicator. However, as the selection of indicators takes into account the availability of data in the countries under study, we consider only the first indicator.

For the human capital subindex, the key considerations are two human capital indicators and three ICT skills indicators. The human capital indicators capture the number of engineers and technicians, which are required to install, operate, and maintain ICT. The indicators are the number of technicians per million inhabitants and the science and engineering enrollment ratios at colleges. Despite the availability of simple ICT devices (e.g., mobile devices) that require little reading skills, the use of the Internet requires a fairly complex set of skills, including technological know-how and reasonable fluency in English. The skills indicators are primary school enrollment (in percent gross amount), secondary school enrollment (in percent gross amount), and tertiary school enrollment (in percent gross amount). However, due to the lack of data availability in the countries under study, we had to exclude the first two indicators. The computation of the human capital subindex is only based on the last three indicators.

8.5 Methodology and Model Specification

The methodology used in this study includes two different methods, resulting in the computation of four e-infrastructure indices. The first method computes the e-infrastructure index nonparametrically, following the normalized human development index (HDI). 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 of the proposed e-infrastructure indices by comparing their outcomes. Consequently, we can suggest the most appropriate e-infrastructure index for widespread use.

8.5.1 Nonparametric E-Infrastructure Index

The nonparametric e-infrastructure 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 [3, 10, 13, 23, 24], the state of the environment [22], human development [26], and the trajectory of development strategy, technology, and research [5, 14].

The basic of our nonparametric e-infrastructure index is a very commonly used index, the United Nation Human Development Program (UNDP) Human Development Index (HDI). Our index differs from the HDI index as we use a different method of weighting than the traditional approach of equal weighting, which is frequently used in the construction of nonparametric indices. The weights of our nonparametric e-infrastructure index are given based on the square of their normalized values. By using this system of weighting, the differences in the performance of countries, which are ranked closely together, become more obvious. The nonparametric e-infrastructure index is then computed as subsequent aggregation of its indicators and subindices, which is shown with the following equation:

$$\text{npindex}_{ct} = \sum_{J}^{j=1} \left\{ \frac{1}{M} \sum_{M}^{m=1} \left\{ \left(x_{jmct} - x_{jmt}^{\min} \right) / \left(x_{jmt}^{\max} - x_{jmt}^{\min} \right) \right\} \right\}^2 \tag{8.1}$$

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

8.5.2 Parametric E-Infrastructure 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. It was originally developed by Pearson [28] and further developed by Hotelling [16]. The method has been employed in many areas including the computation of an environmental index [22] and in the computation of a simple globalization index using trade and financial openness by Agénor [2] and a globalization index by Heshmati [13]. Heshmati and Oh [14] used the method for the computation of the Lisbon development strategy index. Besides, Heshmati et al. [15] used PCA to measure and analyze child well-being in middle- and high-income countries. In short, this method gives a least square solution to the following model:

$$Y_{it} = \sum_{J}^{j=1} \beta_j X_{jit} + E_{it} \tag{8.2}$$

where X_{jit} ($j = 1,2,\ldots,J$) is the indicator score for the year t and the country i. Furthermore, the variable β_j is the factor pattern or eigenvector. The variable 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. Furthermore, researchers, who use the PCA methodology, use the first principal component to get 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 of the principal components in explaining variations in the data. In the aggregation, the share of variance explained by each component is used as weights.

8.6 Analysis and Empirical Results

The summary statistics of the variables are given in Table 8.2. We observed large variations among the variables that are used for calculating the indices. 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 8.2 Summary statistics of e-infrastructure data, 2000–2007

Variable	Number of observations	Mean	Median	Standard derivation	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	36,853
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	23,821	817.91	386,755	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

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)

8.6.1 Estimation of the E-Infrastructure Indices and Their Subindices

8.6.1.1 Nonparametric E-Infrastructure Index

The nonparametric e-infrastructure index is computed for 47 countries over a time period of 8 years starting from 2000 to 2007, using Eq. 8.1. For this, the ten normalized individual indicators have been calculated. After calculating their square values, the indicators have been aggregated first for each subindex and, then, across all subindices.

Based on the nonparametric index for each of the 47 countries, a ranking of the countries under study has been performed (Table 8.3).

Norway is ranked the highest, followed in decreasing order by Sweden, Denmark, Iceland, and Switzerland.

The highest (lowest) contributing component to a country's rank for electricity is Iceland (Djibouti and Yemen), for telecommunications is Iceland (Djibouti), for processing power is Switzerland (Djibouti), for the Internet is Denmark (Djibouti), for broadcasting media is Norway (Djibouti), and for human capital is Australia (Djibouti). The results also show that most OECD countries are ahead of the MENA countries. The only exceptions are three countries (UAE, Bahrain, and Qatar) that belong to the Gulf Cooperation Council (GCC). They are ranked ahead of several OECD countries.

8.6.1.2 Parametric E-Infrastructure Index

For calculating the parametric e-infrastructure index, the first step is to check the correlation structure of the data and find out whether the indicators are correlated. Only if they are correlated, the principal component analysis (PCA) can reduce the number of individual indicators to a small set while preserving the maximum possible proportion of the total variation in the original data set. If the original variables are uncorrelated, the application of PCA is of no value. The result of the correlation check is given in Table 8.4. It shows the correlation coefficients between the index components.

Table 8.4 shows that the components are positively and, some of them, even significantly correlated. Except for the coefficient value of the tertiary education component and the bandwidth component, which shows a negative correlation (−0.071), all other components show a positive correlation. The highest correlation (0.904) 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 (0.804). This is also expected, as fixed telephone lines remain essential for dial-up connections (especially in developing countries) and DSL connections.

Table 8.3 Country ranking according to the nonparametric e-infrastructure index for the period 2000–2007

Obs	Country	electr	telec	proces	intern	media	human	npindex
1	Norway	0.735	0.536	0.492	0.306	0.915	0.564	3.548
2	Sweden	0.291	0.709	0.782	0.518	0.372	0.636	3.309
3	Denmark	0.051	0.696	0.576	0.704	0.390	0.583	3.000
4	Iceland	1.000	0.760	0.344	0.251	0.109	0.475	2.940
5	Switzerland	0.078	0.756	0.963	0.393	0.144	0.335	2.669
6	USA	0.216	0.456	0.789	0.210	0.379	0.509	2.561
7	Netherlands	0.054	0.526	0.634	0.593	0.211	0.528	2.546
8	UK	0.044	0.668	0.490	0.301	0.506	0.452	2.461
9	Canada	0.350	0.383	0.682	0.248	0.235	0.462	2.360
10	Luxembourg	0.300	0.727	0.558	0.335	0.166	0.223	2.308
11	Finland	0.319	0.518	0.337	0.226	0.221	0.664	2.283
12	Australia	0.139	0.455	0.587	0.161	0.203	0.724	2.269
13	Germany	0.057	0.656	0.393	0.194	0.202	0.423	1.925
14	Austria	0.069	0.534	0.434	0.173	0.176	0.408	1.793
15	South Korea	0.060	0.449	0.396	0.192	0.067	0.591	1.754
16	New Zealand	0.103	0.378	0.324	0.186	0.147	0.586	1.723
17	Belgium	0.084	0.461	0.160	0.260	0.132	0.577	1.674
18	France	0.070	0.485	0.342	0.096	0.187	0.486	1.665
19	Ireland	0.043	0.539	0.348	0.087	0.126	0.467	1.611
20	Japan	0.076	0.373	0.260	0.135	0.305	0.410	1.559
21	Italy	0.036	0.603	0.136	0.088	0.143	0.440	1.445
22	Spain	0.039	0.455	0.099	0.066	0.138	0.543	1.339
23	Israel	0.050	0.584	0.098	0.029	0.046	0.453	1.261
24	Greece	0.029	0.547	0.010	0.018	0.121	0.509	1.233
25	Portugal	0.022	0.481	0.027	0.036	0.072	0.514	1.153
26	Czech Rep.	0.043	0.384	0.072	0.052	0.135	0.340	1.026
27	Bahrain	0.141	0.264	0.039	0.021	0.068	0.370	0.904
28	Hungary	0.015	0.307	0.028	0.046	0.101	0.394	0.890
29	UAE	0.201	0.319	0.059	0.049	0.013	0.216	0.857
30	Qatar	0.255	0.205	0.042	0.024	0.074	0.247	0.847
31	Slovak Rep.	0.029	0.197	0.121	0.068	0.067	0.312	0.796
32	Kuwait	0.260	0.153	0.049	0.018	0.067	0.230	0.777
33	Libya	0.008	0.035	0.000	0.000	0.004	0.493	0.541
34	Saudi Arabia	0.049	0.077	0.018	0.006	0.024	0.287	0.460
35	Lebanon	0.005	0.050	0.012	0.015	0.047	0.283	0.412
36	Oman	0.015	0.046	0.003	0.002	0.167	0.170	0.403
37	Jordan	0.003	0.050	0.003	0.004	0.009	0.288	0.356
38	Tunisia	0.001	0.046	0.002	0.003	0.011	0.272	0.336
39	Iran	0.004	0.045	0.010	0.005	0.006	0.235	0.305
40	Egypt	0.001	0.017	0.001	0.002	0.014	0.270	0.304
41	Palestine	0.002	0.015	0.002	0.001	0.004	0.270	0.293
42	Algeria	0.000	0.025	0.000	0.001	0.006	0.243	0.275

(continued)

Table 8.3 (continued)

Obs	Country	electr	telec	proces	intern	media	human	npindex
43	Syria	0.002	0.017	0.002	0.003	0.006	0.223	0.252
44	Iraq	0.001	0.004	0.027	0.006	0.030	0.112	0.181
45	Morocco	0.000	0.022	0.000	0.005	0.005	0.125	0.157
46	Yemen	0.000	0.001	0.000	0.000	0.037	0.072	0.111
47	Djibouti	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 8.4 Correlation matrix

	elect	fixed	cell	inter	compu	broadb	tvse	prim	seco	tert
elect	1									
fixed	0.587	1								
cell	0.505	0.639	1							
inter	0.634	0.784	0.717	1						
compu	0.584	0.804	0.623	0.904	1					
broadb	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	0.012	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

Table 8.5 Eigenvalues of the correlation matrix

Principal component	Eigenvalue	Proportion	Cumulative
1	5.4765	0.5476	0.5476
2	1.1856	0.1186	0.6662
3	1.0235	0.1023	0.7686
4	0.5564	0.0556	0.8242

As the correlation check revealed a strong correlation, the PCA can be applied. For this, we calculate the eigenvalues, the percentage of variance explained in each component, and the total variance explained by all components. Those values are shown in Table 8.5.

The next step is to identify the number of principal components that should be considered for 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. Consequently, three principal components should be considered in the analysis of the parametric e-infrastructure index (Table 8.5). Their eigenvalue is greater than one.

The first principal component explains the variance in all the individual indicators (with an eigenvalue of 5.4765) more than all other principal components. The second principal component explains the remaining variance with an eigenvalue of 1.1856 the best. The third principal component has an eigenvalue of 1.0235.

Table 8.6 Eigenvectors of the principal components

	prin1	prin2	prin3	prin4
elect	0.3031	−0.206	−0.0050	0.8309
fixed	0.3808	0.0068	−0.0240	−0.0960
cell	0.3333	0.0224	0.1516	0.1039
Internet	0.3936	−0.1790	−0.0260	−0.0890
compu	0.3759	−0.2100	−0.0350	−0.1160
broadb	0.0327	−0.3210	0.9014	−0.1820
tvse	0.3245	−0.2010	−0.1560	−0.0870
prim	0.1251	0.7599	0.3287	0.1849
seco	0.3372	0.3577	0.0583	−0.0240
tert	0.3467	0.1787	−0.1620	−0.4390

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 8.6. An eigenvector value, which is larger than 0.3, indicates that an indicator has a significant contribution to the component. Its sign indicates the direction of the contribution. Although each indicator usually plays a significant role to only one principal component, some indicators are explained in two principal components (e.g., primary and secondary school enrollments). To address this, we use a weighted average of the three principal components.

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

$$\begin{aligned}\text{prin123} = \text{prin1}^* (0.5476/0.7686) + \text{prin2}^* (0.1186/0.7686) \\ + \text{prin3}^* (0.1023/0.7686)\end{aligned} \tag{8.3}$$

The results of the parametric e-infrastructure index calculation for all 47 countries and the ranking of the 47 countries are given in Table 8.7. To simplify the comparison of both indices, the nonparametric e-infrastructure index is listed in Table 8.7 as well. Similar to the nonparametric index, the results show that OECD countries are ahead of the MENA countries with the exception of Israel and Bahrain. They are ranked ahead of several OECD countries.

The ranking based on the result of the parametric method shows Sweden, Norway, Australia, Denmark, and Iceland at the top of the list. This ranking of the top performers shows some slight differences to the ranking of the nonparametric e-infrastructure index. For example, Norway and Sweden swap their positions. Norway is ranked 2nd, while it is ranked 1st according to the nonparametric e-infrastructure index, and Sweden is ranked 1st, while it is ranked 2nd according to the nonparametric e-infrastructure index. The highest difference in position is observed in case of Australia. It has been ranked 12th in the nonparametric e-infrastructure index but is ranked 3rd in the parametric e-infrastructure index.

Table 8.7 Comparison of the nonparametric and the parametric e-infrastructure indices, 2000–2007, 376 observations

Parametric e-infrastructure index			Nonparametric e-infrastructure index		
Rank by prin123	Country	prin123	Rank by npindex	Country	npindex
1	Sweden	1.014	2	Sweden	3.309
2	Norway	0.940	1	Norway	3.548
3	Australia	0.890	12	Australia	2.269
4	Denmark	0.809	3	Denmark	3.000
5	Iceland	0.794	4	Iceland	2.940
6	Finland	0.751	11	Finland	2.283
7	Netherlands	0.728	7	Netherlands	2.546
8	USA	0.582	6	USA	2.561
9	UK	0.578	8	UK	2.461
10	Luxembourg	0.573	10	Luxembourg	2.308
11	Belgium	0.560	17	Belgium	1.674
12	Canada	0.531	9	Canada	2.360
13	New Zealand	0.527	16	New Zealand	1.723
14	Switzerland	0.496	5	Switzerland	2.669
15	South Korea	0.495	15	South Korea	1.754
16	Germany	0.468	13	Germany	1.925
17	France	0.463	18	France	1.665
18	Ireland	0.402	19	Ireland	1.611
19	Austria	0.385	14	Austria	1.793
20	Portugal	0.383	25	Portugal	1.153
21	Spain	0.381	22	Spain	1.339
22	Italy	0.318	21	Italy	1.445
23	Japan	0.296	20	Japan	1.559
24	Israel	0.290	23	Israel	1.261
25	Greece	0.158	24	Greece	1.233
26	Bahrain	0.087	27	Bahrain	0.904
27	Czech Rep.	0.021	26	Czech Rep.	1.026
28	Hungary	−0.062	28	Hungary	0.890
29	Slovak Rep.	−0.151	31	Slovak Rep.	0.796
30	Qatar	−0.190	30	Qatar	0.847
31	UAE	-0.248	29	UAE	0.857
32	Libya	−0.268	33	Libya	0.541
33	Kuwait	−0.348	32	Kuwait	0.777
34	Saudi Arabia	−0.398	34	Saudi Arabia	0.460
35	Tunisia	−0.562	38	Tunisia	0.336
36	Lebanon	−0.608	35	Lebanon	0.412
37	Jordan	−0.612	37	Jordan	0.356
38	Iran	−0.671	39	Iran	0.305
39	Algeria	−0.690	42	Algeria	0.275
40	Syria	−0.693	43	Syria	0.252

(continued)

Table 8.7 (continued)

Parametric e-infrastructure index			Nonparametric e-infrastructure index		
Rank by prin123	Country	prin123	Rank by npindex	Country	npindex
41	Egypt	−0.701	40	Egypt	0.304
42	Palestine	−0.792	41	Palestine	0.293
43	Oman	−0.843	36	Oman	0.403
44	Morocco	−1.029	45	Morocco	0.157
45	Iraq	−1.161	44	Iraq	0.181
46	Yemen	−1.454	46	Yemen	0.111
47	Djibouti	−2.438	47	Djibouti	0.000

prin123 = prin1 * (0.5476 / 0.7686) + prin2 * (0.1186 / 0.7686) + prin3 * (0.1023 / 0.7686)

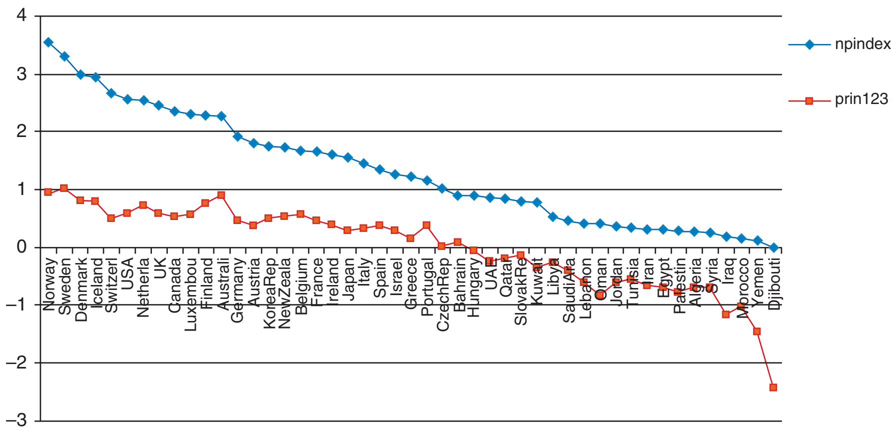


Fig. 8.1 Comparison of nonparametric (npindex) and parametric (prin123) e-infrastructure indices, 2000 and 2007, sorted by npindex in descending order

Comparing the ranking of all countries according to both e-infrastructure indices in Fig. 8.1, the ranking results look similar though. The differences in ranking of each country are little as well as the variation in ranking positions. The nonparametric e-infrastructure index (npindex) is sorted in descending order, providing homogeneously distributed values. It results in almost a linear curve. The parametric e-infrastructure index (prin123) 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 only, Djibouti and Australia.

In addition to this, both rankings show that the low ranks of some countries are to some extent linked to their economic condition. While poor countries from MENA have low ranks, rich MENA countries (e.g., the Gulf Cooperation Council (GCC) countries) have made remarkable developments. They are not only leading the ranking of MENA countries but they are also higher ranked than a few OECD countries.

8.6.2 Analysis of Heterogeneity in Both E-Infrastructure Indices

Variations in the values of the e-infrastructure indices and their components can be the result of the situation of a country, its geographical location (i.e., regions), and the changes over time. In this section, we will analyze the heterogeneity of countries with respect to these three factors in more detail.

8.6.2.1 Country Heterogeneity in E-Infrastructure Development

The results of the nonparametric e-infrastructure index shows that the performance of countries differs by components (Table 8.8). It also shows that there is no dependency between components, i.e., if a country performed well in one component, it does not mean that it also performs well in another component. An example is Norway, which is ranked 1st, in broadcasting media. It has neither the highest score in electricity (2nd), telecommunication (12th), computers (9th), Internet (6th), nor human capital (8th). With the exception of Iceland, there is no country that gains the highest score in more than one of the six components. However, despite its highest scores in both electricity and telecommunication components, Iceland is only ranked 4th. It shows low performance in the other components (computer 15th, broadcasting media 24th, Internet 9th, and human capital 16th). Denmark, which is ranked 3rd, has the highest Internet score among all countries and a low electricity consumption (22nd).

Among the low-ranked countries, we find that some MENA countries, particularly Gulf countries, perform relatively well in terms of electricity (UAE is 10th, Qatar is 8th, and Kuwait is 7th). Despite their significant improvements in the last few years, especially with respect to mobile and Internet penetration, their low rank is caused by their poor performance in the early years (2000–2003). The other low-ranked countries still have a poor performance in all e-infrastructure components compared with the high-ranked countries.

8.6.2.2 Regional Heterogeneity in E-Infrastructure Development

This analysis is based on grouping the countries by their geographical location and their membership to the OECD. Countries are grouped into four groups: Middle East, North Africa, European, and other non-European OECD countries. Although the OECD group includes countries from different continents, many countries are from Europe. Therefore, we grouped the OECD countries into two groups: European OECD countries and non-European OECD countries. Despite the fact that the non-European OECD countries are from different continents, these countries share similar characteristics, including the level of economic growth and the type of economic system.

Table 8.8 The distribution of the nonparametric index and its decomposition, 2000–2007, 376 observations

Country	electr		telec		proces		intern		media		human		Nonparametric e-infrastructure index (npindex)	
	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value
Norway	2	0.735	12	0.536	9	0.492	6	0.306	1	0.915	8	0.564	1	3.548
Sweden	6	0.291	4	0.709	3	0.782	3	0.518	5	0.372	3	0.636	2	3.309
Denmark	22	0.051	5	0.696	7	0.576	1	0.704	3	0.390	6	0.583	3	3.000
Iceland	1	1.000	1	0.760	15	0.344	9	0.251	24	0.109	16	0.475	4	2.940
Switzerland	15	0.078	2	0.756	1	0.963	4	0.393	17	0.144	28	0.335	5	2.669
USA	9	0.216	19	0.456	2	0.789	12	0.210	4	0.379	12	0.509	6	2.561
Netherlands	21	0.054	14	0.526	5	0.634	2	0.593	9	0.211	10	0.528	7	2.546
UK	25	0.044	6	0.668	10	0.490	7	0.301	2	0.506	20	0.452	8	2.461
Canada	3	0.350	24	0.383	4	0.682	10	0.248	7	0.235	18	0.462	9	2.360
Luxembourg	5	0.300	3	0.727	8	0.558	5	0.335	15	0.166	40	0.223	10	2.308
Finland	4	0.319	15	0.518	17	0.337	11	0.226	8	0.221	2	0.664	11	2.283
Australia	12	0.139	20	0.455	6	0.587	17	0.161	10	0.203	1	0.724	12	2.269
Germany	20	0.057	7	0.656	13	0.393	13	0.194	11	0.202	22	0.423	13	1.925
Austria	18	0.069	13	0.534	11	0.434	16	0.173	13	0.176	24	0.408	14	1.793
South Korea	19	0.060	22	0.449	12	0.396	14	0.192	29	0.067	4	0.591	15	1.754
New Zealand	13	0.103	25	0.378	18	0.324	15	0.186	16	0.147	5	0.586	16	1.723
Belgium	14	0.084	18	0.461	20	0.160	8	0.260	21	0.132	7	0.577	17	1.674
France	17	0.070	16	0.485	16	0.342	19	0.096	12	0.187	15	0.486	18	1.665
Ireland	26	0.043	11	0.539	14	0.348	21	0.087	22	0.126	17	0.467	19	1.611
Japan	16	0.076	26	0.373	19	0.260	18	0.135	6	0.305	23	0.410	20	1.559
Italy	29	0.036	8	0.603	21	0.136	20	0.088	18	0.143	21	0.440	21	1.445
Spain	28	0.039	21	0.455	23	0.099	23	0.066	19	0.138	9	0.543	22	1.339
Israel	23	0.050	9	0.584	24	0.098	28	0.029	33	0.046	19	0.453	23	1.261

(continued)

Table 8.8 (continued)

Country	electr		telec		proces		intern		media		human		Nonparametric e-infrastructure index (npindex)	
	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value
Greece	30	0.029	10	0.547	35	0.010	32	0.018	23	0.121	13	0.509	24	1.233
Portugal	32	0.022	17	0.481	31	0.027	27	0.036	27	0.072	11	0.514	25	1.153
Czech Rep.	27	0.043	23	0.384	25	0.072	24	0.052	20	0.135	27	0.340	26	1.026
Bahrain	11	0.141	29	0.264	29	0.039	30	0.021	28	0.068	26	0.370	27	0.904
Hungary	33	0.015	28	0.307	30	0.028	26	0.046	25	0.101	25	0.394	28	0.890
UAE	10	0.201	27	0.319	26	0.059	25	0.049	38	0.013	42	0.216	29	0.857
Qatar	8	0.255	30	0.205	28	0.042	29	0.024	26	0.074	36	0.247	30	0.847
Slovak Rep.	31	0.029	31	0.197	22	0.121	22	0.068	30	0.067	29	0.312	31	0.796
Kuwait	7	0.260	32	0.153	27	0.049	31	0.018	31	0.067	39	0.230	32	0.777
Libya	35	0.008	39	0.035	43	0.000	45	0.000	46	0.004	14	0.493	33	0.541
Saudi Arabia	24	0.049	33	0.077	33	0.018	35	0.006	36	0.024	31	0.287	34	0.460
Lebanon	36	0.005	34	0.050	34	0.012	33	0.015	32	0.047	32	0.283	35	0.412
Oman	34	0.015	36	0.046	38	0.003	41	0.002	14	0.167	43	0.170	36	0.403
Jordan	38	0.003	35	0.050	37	0.003	38	0.004	40	0.009	30	0.288	37	0.356
Tunisia	41	0.001	37	0.046	39	0.002	39	0.003	39	0.011	33	0.272	38	0.336
Iran	37	0.004	38	0.045	36	0.010	36	0.005	41	0.006	38	0.235	39	0.305
Egypt	42	0.001	43	0.017	42	0.001	42	0.002	37	0.014	34	0.270	40	0.304
Palestine	39	0.002	44	0.015	41	0.002	43	0.001	45	0.004	35	0.270	41	0.293
Algeria	44	0.000	40	0.025	44	0.000	44	0.001	43	0.006	37	0.243	42	0.275
Syria	40	0.002	42	0.017	40	0.002	40	0.003	42	0.006	41	0.223	43	0.252
Iraq	43	0.001	45	0.004	32	0.027	34	0.006	35	0.030	45	0.112	44	0.181
Morocco	45	0.000	41	0.022	45	0.000	37	0.005	44	0.005	44	0.125	45	0.157
Yemen	46	0.000	46	0.001	46	0.000	46	0.000	34	0.037	46	0.072	46	0.111
Djibouti	47	0.000	47	0.000	47	0.000	47	0.000	47	0.000	47	0.000	47	0.000

Table 8.9 Mean e-infrastructure indices by region, 2000–2007, 376 observations

Rank	Region	electr	telec	proces	intern	media	human	Nonparametric e-infrastructure index (npindex)	Parametric e-infrastructure index (prin123)
1	Non-European OECD countries	0.278	0.465	0.483	0.198	0.206	0.537	2.166	0.588
2	European OECD countries	0.120	0.539	0.350	0.228	0.226	0.470	1.934	0.461
3	Middle East countries	0.070	0.131	0.026	0.013	0.043	0.247	0.530	−0.546
4	North Africa countries	0.002	0.024	0.001	0.002	0.007	0.234	0.269	−0.948

As expected, both types of e-infrastructure indices show that the non-European OECD countries and the European OECD regions have the highest e-infrastructure scores (Table 8.9). The Middle East region holds the third rank, and the North African region comes out at the bottom of the list.

The non-European OECD region and the European OECD countries differ in the values of the components. For instance, the non-European OECD countries are advantageous in terms of electricity consumption, computers, and human capital, while the European OECD region has a much higher level of telecommunication. In terms of Internet and broadcasting media, they are at a similar level. Despite their progress in the human capital component, the Middle East and North Africa regions still show a relatively low level in all of the other e-infrastructure components. The gap between MENA and the OECD is quite large, as depicted in Fig. 8.2.

Furthermore, given the close relationship between e-infrastructure levels and GDP, most of MENA countries are still lagging behind in terms of e-infrastructure compared with OECD countries. The North Africa region is identified as the least developed region in e-infrastructure. Thus, the low rank of countries is to large extent linked to their economic conditions and their inability to address these issues effectively.

8.6.2.3 Development of E-Infrastructure Over Time

Eight years (2000–2007) is a relatively long period in terms of information and communication technology (ICT) development. ICT technology, infrastructure, and access values may change considerably as a result of the introduction of new technologies, enhanced investments, changes in the market environment, or price cuts. Therefore, the e-infrastructure indices are expected to show large changes over a period of 8 years.

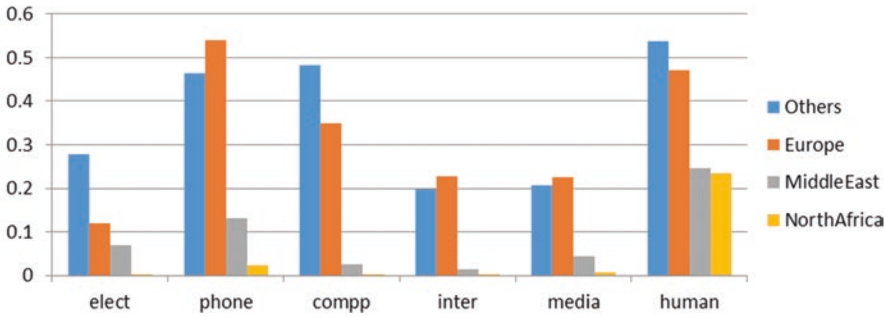
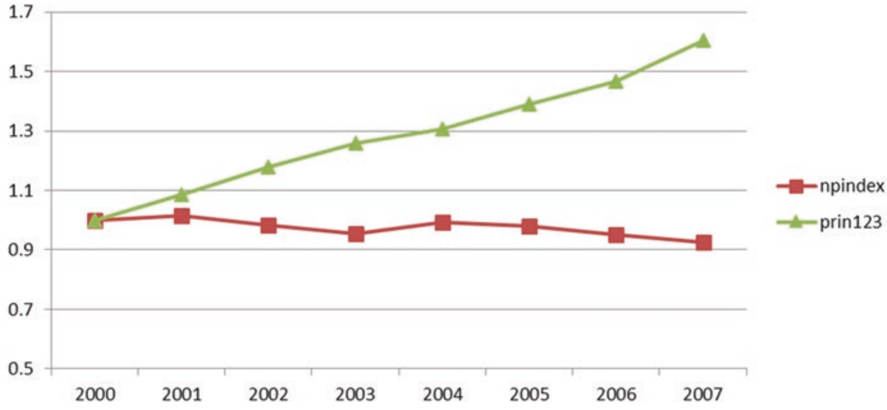


Fig. 8.2 Region heterogeneity of components of the nonparametric e-infrastructure index, 2000–2007

Looking at Fig. 8.3a, in which the indices are normalized at their 2,000 values to ease comparison of their development over time, it can be observed that the parametric e-infrastructure index continuously increased over time. The nonparametric index increased from 2000 to 2001 from 1.000 to 1.016. Afterwards, however, it declined to 0.953 in 2002 and remained at this level until 2005. Then, it declined again to 0.925 in 2007 suggesting 7.5 percent decline in the period. In contrast, the parametric index is continuously increasing from 1.000 in 2000 to 1.604 in 2007, suggesting 60.4% increase during the period studied. The individual country level index development shown in Fig. 8.3b confirms the gap pattern between the two indices. The decline after 2000 is very likely attributed to the global IT bubble. The difference in development of the two indices over time is a result of difference in weights attached to each indicator. Therefore, the parametric e-infrastructure index development is consistent with expectations and, therefore, preferable.

8.6.3 *Efficiency in E-Infrastructure Development*

In Table 8.10, we report the efficiency of countries in terms of e-infrastructure development. The efficiency of a country is the comparison of the country with the country that has the best-practiced e-infrastructure (i.e., the highest e-infrastructure value). The efficiency measure is in the interval 0 to 1, where 0 is assigned to the country with the lowest score and 1 to the country with the highest score. The measure is computed for the two e-infrastructure indices. It should be noted that the efficiency measure not only shows the rank but also the metric distance to the frontier e-infrastructure and it is easily interpretable as percentage points. Thus, the distance to the best in the e-infrastructure index is quantitatively measured. Concerning the nonparametric e-infrastructure index, Norway is serving as the reference country, while, in the case of the parametric e-infrastructure index, Sweden is the reference country.



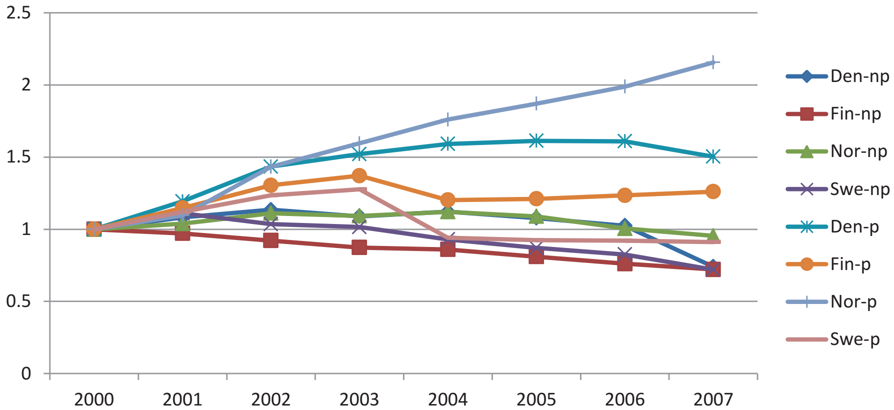


Fig. 8.3 Development of nonparametric and parametric e-infrastructure indices over time: (**a**) normalized at 2000 level and averaged over all countries (npindex and prin123); (**b**) normalized at 2000 level for Scandinavian countries. The nonparametric and parametric indices are indicated with a "np" and "p," respectively

The values of the two efficiencies for each country are shown in Fig. 8.4. In general, both methods show similar performances. Only in a few cases, we observe a significant shift in the position of countries.

We find a wide range of variation in the efficiency among countries. For instance, in the case of the nonparametric index, the efficiency rate of MENA countries is below 50% of the frontier country. It shows that MENA countries perform very poorly compared to the frontier country in terms of e-infrastructure. The efficiency measure for the parametric e-infrastructure index shows that some MENA countries, particularly Bahrain, Qatar, and the UAE, achieve an efficiency of more than 50 performance points (Bahrain 0.7315, Qatar 0.6512, and UAE 0.63). In case of Djibouti, which is placed at the bottom of the efficiency distribution of the two indices, the efficiency is zero.

Table 8.10 Two efficiency measures based on the mean parametric and nonparametric e-infrastructure indices, 2000–2007 (countries are ranked by parametric index), 376 observations

Country	Nonparametric e-infrastructure index (npindex)	Parametric e-infrastructure index (prin123)	Efficiency with respect to the best nonparametric e-infrastructure index	Efficiency with respect to the best parametric e-infrastructure index
Sweden	3.309	1.014	0.9326	1.0000
Norway	3.548	0.940	1.0000	0.9786
Australia	2.269	0.890	0.6395	0.9641
Denmark	3000	0.809	0.8455	0.9406
Iceland	2.940	0.794	0.8286	0.9363
Finland	2.283	0.751	0.6435	0.9238
Netherlands	2.546	0.728	0.7176	0.9171
USA	2.561	0.582	0.7218	0.8749
UK	2.461	0.578	0.6936	0.8737
Luxembourg	2.308	0.573	0.6505	0.8722
Belgium	1.674	0.560	0.4718	0.8685
Canada	2.360	0.531	0.6652	0.8601
New Zealand	1.723	0.527	0.4856	0.8589
Switzerland	2.669	0.496	0.7523	0.8499
South Korea	1.754	0.495	0.4944	0.8497
Germany	1.925	0.468	0.5426	0.8418
France	1.665	0.463	0.4693	0.8404
Ireland	1.611	0.402	0.4541	0.8227
Austria	1.793	0.385	0.5054	0.8178
Portugal	1.153	0.383	0.3250	0.8172
Spain	1.339	0.381	0.3774	0.8166
Italy	1.445	0.318	0.4073	0.7984
Japan	1.559	0.296	0.4394	0.7920
Israel	1.261	0.290	0.3554	0.7903
Greece	1.233	0.158	0.3475	0.7520
Bahrain	0.904	0.087	0.2548	0.7315
Czech Rep.	1.026	0.021	0.2892	0.7123
Hungary	0.890	−0.062	0.2508	0.6883
Slovak Rep.	0.796	−0.151	0.2244	0.6625
Qatar	0.847	−0.190	0.2387	0.6512
UAE	0.857	−0.248	0.2415	0.6344
Libya	0.541	−0.268	0.1525	0.6286
Kuwait	0.777	−0.348	0.2190	0.6054
Saudi Arabia	0.460	−0.398	0.1297	0.5910
Tunisia	0.336	−0.562	0.0947	0.5435
Lebanon	0.412	−0.608	0.1161	0.5301
Jordan	0.356	−0.612	0.1003	0.5290

(continued)

Table 8.10 (continued)

Country	Nonparametric e-infrastructure index (npindex)	Parametric e-infrastructure index (prin123)	Efficiency with respect to the best nonparametric e-infrastructure index	Efficiency with respect to the best parametric e-infrastructure index
Iran	0.305	−0.671	0.0860	0.5119
Algeria	0.275	−0.690	0.0775	0.5064
Syria	0.252	−0.693	0.0710	0.5055
Egypt	0.304	−0.701	0.0857	0.5032
Palestine	0.293	−0.792	0.0826	0.4768
Oman	0.403	−0.843	0.1136	0.4621
Morocco	0.157	−1.029	0.0443	0.4082
Iraq	0.181	−1.161	0.0510	0.3699
Yemen	0.111	−1.454	0.0313	0.2851
Djibouti	0.000	−2.438	0.0000	0.0000

effnpindex = npindex/3.548; effprin123 = (prin123 + 2.438)/(1.014 + 2.438)

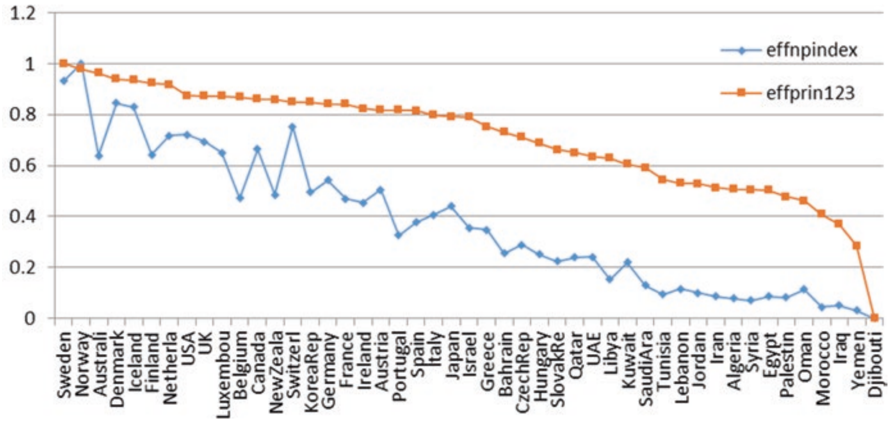


Fig. 8.4 Efficiency based on mean parametric (effprin123) and nonparametric (effnpindex) e-infrastructure indices, 2000–2007, sorted by parametric index in descending order

8.6.4 Comparison Between Different Types of Parametric and Nonparametric Indices

In this section, our nonparametric index, in which each component is given weight by squaring its value, is compared with the human-development-index-type (HDI-type) index, which is based on equal weighting. Besides, our parametric index, which is based on several principal components with eigenvalues greater than 1.0, is compared with the traditional approach that uses only the first principal component. The aim of the comparisons is to see the effect of the new approaches on the ranking of countries.

8.6.4.1 Effect of the New Approach of the Nonparametric E-Infrastructure Indices

Table 8.11 presents the results of our nonparametric index and the HDI-type index. Our method for computing the nonparametric index is compared with the HDI-type index. The nonparametric HDI-type index is based on the ad hoc assignment of weights for the aggregation of the components. For our index, the components are squared before aggregation to give high weights to those with high values. As a result of giving higher weights to the countries with high values, the rank of countries changes compared with those based on the HDI-type index. For instance, among the highest-ranked countries, the Netherlands and Canada swap their positions 5th (6th). The same occurs with Switzerland and the USA 7th (9th). Norway is ranked as the highest in both indices. Iceland, Luxembourg, Sweden, the UK, and Australia keep their positions without change (2nd, 3rd, 4th, 8th, and 10th, respectively). Surprisingly, Portugal and the Slovak Republic swap their positions 27th (31st). Among the MENA countries, the UAE, Kuwait, Saudi Arabia, and Iran keep their positions (ranked 23th, 33rd, 34th, and 35th, respectively). Also, Iraq, Yemen, and Djibouti keep their ranks at the bottom of the table at 45th, 46th, and 47th, respectively (Fig. 8.5).

8.6.4.2 Effect of the New Approach of the Parametric E-Infrastructure Index

Traditionally, researchers, who use the principal component analysis methodology, use the first principal component to arrive at a single measurement scale. In this study, we computed the index based on the weighted average of the three principal components. In this way, we utilize the explaining power of all significant principal components. The result of the calculation of both indices is shown in Table 8.12.

If we rank countries by the index (prin1) that is based on the first principal component, the rank of some countries is changed significantly compared to our approach. For instance, Luxembourg moved down eight places, from 1st to 9th. That is to be expected because the result of the principal component analysis shows that prin1 does not count the contribution of the international Internet bandwidth indicator and primary enrollment indicator. They were represented in the second (prin2) and third principal component (prin3) but not in the first principal component (prin1). Luxembourg has made a remarkable increase in the international Internet bandwidth indicator (7.5 Mbit/sec per inhabitant in 2007, the highest among all countries) due to the new fiber network deployed by Luxembourg's incumbent operator P&T in 2007 (Fig. 8.6). Another country, which has a lower rank, is Bahrain. It moved down from 18th to 25th. This is also due to the fact that prin1 does not count the contribution of the primary enrollment indicator. Bahrain has the highest value among all the countries surveyed. Countries which decreased in the ranking are Australia, Finland, France, Germany, New Zealand, Korea, Ireland, Spain, Portugal, Qatar, Libya, Iran, Syria, Tunisia, Algeria, and Morocco. Denmark, Italy, Belgium, Egypt, Iraq, Yemen, and Djibouti kept their positions. The remaining countries increased in the ranking.

Table 8.11 Comparison between nonparametric e-infrastructure indices, 2000–2007, 376 observations

Rank by squared components nonparametric index	Country	npindex	Rank by nonparametric index without squaring its components	Country	npindex2
1	Norway	3.038	1	Norway	4.171
2	Iceland	2.588	2	Iceland	3.579
3	Luxembourg	2.517	3	Luxembourg	3.554
4	Sweden	2.364	4	Sweden	3.540
5	Netherlands	2.236	6	Netherlands	3.325
6	Canada	2.225	5	Canada	3.369
7	Switzerland	2.039	9	Switzerland	3.086
8	UK	1.952	8	UK	3.117
9	USA	1.931	7	USA	3.225
10	Australia	1.909	10	Australia	3.042
11	Germany	1.790	13	Germany	2.948
12	Denmark	1.713	12	Denmark	2.962
13	Finland	1.666	11	Finland	3.004
14	France	1.628	14	France	2.800
15	Ireland	1.541	18	Ireland	2.675
16	South Korea	1.540	16	South Korea	2.728
17	New Zealand	1.511	15	New Zealand	2.766
18	Austria	1.449	17	Austria	2.722
19	Italy	1.422	20	Italy	2.600
20	Belgium	1.279	21	Belgium	2.542
21	Spain	1.254	22	Spain	2.400
22	Japan	1.237	19	Japan	2.608
23	UAE	1.202	23	UAE	2.367
24	Greece	1.175	25	Greece	2.084
25	Bahrain	1.023	24	Bahrain	2.126
26	Israel	1.021	29	Israel	2.002
27	Portugal	0.992	31	Portugal	1.970
28	Slovak Rep.	0.908	26	Slovak Rep.	2.064
29	Qatar	0.890	28	Qatar	2.028
30	Hungary	0.887	30	Hungary	1.999
31	Czech Rep.	0.883	27	Czech Rep.	2.052
32	Kuwait	0.691	32	Kuwait	1.890
33	Saudi Arabia	0.563	33	Saudi Arabia	1.521
34	Libya	0.543	37	Libya	1.125
35	Iran	0.451	35	Iran	1.192
36	Lebanon	0.392	34	Lebanon	1.215
37	Jordan	0.368	38	Jordan	1.115

(continued)

Table 8.11 (continued)

Rank by squared components nonparametric index	Country	npindex	Rank by nonparametric index without squaring its components	Country	npindex2
38	Tunisia	0.359	39	Tunisia	1.036
39	Algeria	0.338	42	Algeria	0.901
40	Egypt	0.338	41	Egypt	0.941
41	Oman	0.332	36	Oman	1.178
42	Syria	0.318	40	Syria	0.958
43	Palestine	0.250	45	Palestine	0.766
44	Morocco	0.195	44	Morocco	0.772
45	Iraq	0.190	43	Iraq	0.821
46	Yemen	0.084	46	Yemen	0.462
47	Djibouti	0.000	47	Djibouti	0.017

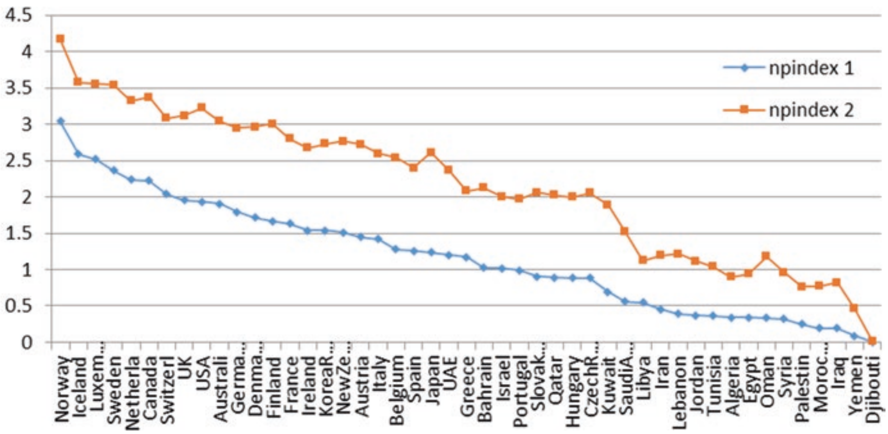


Fig. 8.5 Nonparametric e-infrastructure indices, 2000–2007, sorted by npindex 1 in descending order

8.7 Discussion and Implications

8.7.1 Guidelines for Improving the Index

There is a growing amount of literature on the measurement of e-readiness across countries such as e-government, e-commerce, and other ICT developments. However, the e-infrastructure, which is considered as the basis for such development, is not investigated much.

Table 8.12 Comparison between parametric e-infrastructure indices, 2000–2007, 376 observations

Rank by prin123	Country	prin123	Rank by prin1	Country	prin1
1	Luxembourg	2.226	9	Luxembourg	1.276
2	Norway	1.257	1	Norway	2.497
3	Australia	1.042	8	Australia	1.308
4	Netherlands	1.008	4	Netherlands	1.466
5	Iceland	0.950	3	Iceland	1.604
6	Sweden	0.888	2	Sweden	1.618
7	Denmark	0.849	7	Denmark	1.309
8	Finland	0.779	10	Finland	1.268
9	France	0.737	16	France	0.929
10	Germany	0.735	12	Germany	1.080
11	New Zealand	0.735	14	New Zealand	1.045
12	USA	0.714	6	USA	1.321
13	Canada	0.707	5	Canada	1.325
14	South Korea	0.704	15	South Korea	0.957
15	UK	0.681	11	UK	1.180
16	Ireland	0.672	18	Ireland	0.865
17	Italy	0.669	17	Italy	0.885
18	Bahrain	0.652	25	Bahrain	0.337
19	Spain	0.629	22	Spain	0.723
20	Switzerland	0.591	13	Switzerland	1.066
21	Belgium	0.564	21	Belgium	0.781
22	Austria	0.536	19	Austria	0.853
23	Portugal	0.474	27	Portugal	0.294
24	Japan	0.443	20	Japan	0.818
25	Greece	0.437	23	Greece	0.523
26	UAE	0.423	24	UAE	0.446
27	Israel	0.379	29	Israel	0.252
28	Qatar	0.313	31	Qatar	0.201
29	Czech Rep.	0.227	28	Czech Rep.	0.281
30	Hungary	0.174	26	Hungary	0.311
31	Slovak Rep.	0.165	30	Slovak Rep.	0.203
32	Saudi Arabia	−0.010	33	Saudi Arabia	−0.289
33	Kuwait	−0.123	32	Kuwait	−0.092
34	Libya	−0.152	35	Libya	−0.585
35	Iran	−0.167	38	Iran	−0.676
36	Syria	−0.316	42	Syria	−0.958
37	Tunisia	−0.390	39	Tunisia	−0.765
38	Algeria	−0.392	41	Algeria	−0.893
39	Jordan	−0.444	37	Jordan	−0.641
40	Egypt	−0.475	40	Egypt	−0.860
41	Lebanon	−0.485	34	Lebanon	−0.584
42	Oman	−0.662	36	Oman	−0.618

(continued)

Table 8.12 (continued)

Rank by prin123	Country	prin123	Rank by prin1	Country	prin1
43	Morocco	–0.726	44	Morocco	–1.174
44	Palestine	–0.894	43	Palestine	–1.036
45	Iraq	–0.932	45	Iraq	–1.242
46	Yemen	–1.294	46	Yemen	–1.558
47	Djibouti	–2.261	47	Djibouti	–2.137

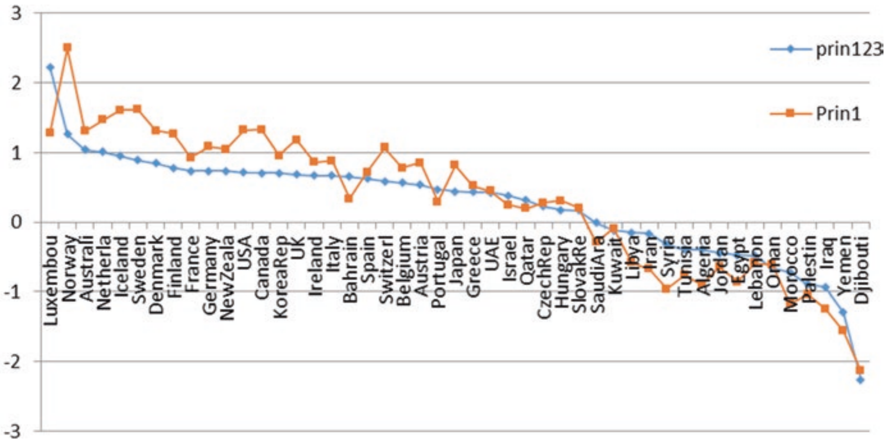


Fig. 8.6 Parametric e-infrastructure indices, (weighted and first principal component based), 2000–2007, sorted by weighted index (prin123) in descending order

This study serves as a major first step toward establishing a proper composite e-infrastructure index. The e-infrastructure index covers all of the related infrastructure components, including electricity, telecommunication, Internet, processing power, broadcasting, and human capital. A breakdown of the index into major components provides the possibility to track each component separately and to identify the strengths and weaknesses of each country in different e-infrastructure areas.

Despite the significant effort made in the construction of the e-infrastructure index, several essential improvements are still possible. One improvement can be achieved by using recent data (i.e., data for the years 2008 and later).

As a consequence of the unavailability of data, especially for MENA countries, particular indicators such as fixed-line broadband Internet subscribers, mobile broadband Internet subscribers, cable television subscribers per households, home satellite antennas, technicians, and engineers were excluded from the study. These additional factors were believed to be relevant and important for creating the e-infrastructure index. With the addition of these indicators, we would have been able to observe the level of e-infrastructure development more accurately.

Using our indices, it would be interesting to investigate how the land size of a country and the size of the urban population impact e-infrastructure development. It is easier to speed up the development of e-infrastructure in a country with a small area and high urban population compared to a large country with scattered populations in rural areas.

It would be also interesting to use our indices to observe the impact of a country's willingness to spend money on the level of the e-infrastructure of the country.

8.7.2 *Policy Recommendations*

The two types of the multidimensional e-infrastructure indices, parametric and nonparametric, serve as important tools to measure the level of e-infrastructure development among countries and regions and provide useful information about the strengths and weaknesses of the countries in different technological infrastructure areas. The e-infrastructure index can help policy makers with the opportunity to point out the source of the failures they encounter when they are developing their e- infrastructure and allow them to adapt and develop policies for enhancing it accordingly. Based on the results of the study, it should be noted that:

1. The indicators of the e-infrastructure indices showed their significant contribution in determining the level of e-infrastructure development. These indicators have to be focused well in the national policy of all countries. Moving toward developing its e-infrastructure, the government should allocate a significant share or proportion of their annual budget to invest on these indicators.
2. For a country to exploit the potential of ICT, there is a need for the availability of e-infrastructure. Therefore, a country should not only invest in ICT but rather in all technological infrastructure areas that are prerequisites for subsequent access and use of ICT. Based on the results presented by the e-infrastructure indices, many countries in the MENA region suffer from a lack of the basic infrastructure (i.e., electricity) needed to build a solid e-infrastructure base. Therefore, these countries should increase their investments to provide solutions to the basic problems, which are still considered an obstacle for ICT uptake.
3. It is clear that MENA countries still lag behind in the provision of e-services as a result of their poor e-infrastructure. Despite the significant improvements in different areas of e-infrastructure, especially in mobile and Internet penetrations, MENA countries need to increase their investments in the development of their e-infrastructure. Early investment in the provision of that infrastructure can potentially bring faster and more radical changes in the future of the socioeconomic development of these countries.
4. The results show that MENA countries have made a significant improvement in mobile technology. Of course, this is related to the strong relationship between market liberalization and mobile diffusion. Open competition between mobile companies has played a significant role in the dramatic mobile penetration growth in MENA countries. In order to achieve the same growth in the Internet, MENA countries should duplicate this policy with regard to the Internet sector,

which is currently monopolized by the government. The policy should focus on motivating the private sector to invest in e- infrastructure development.

5. Internet quality and connectivity are a vital piece of infrastructure for any country with regard to its ICT development. Therefore, countries should invest in developing their international Internet bandwidth as a crucial backbone infrastructure. Without the necessary international Internet bandwidth, access to the resources of the Internet remains slow and expensive.
6. The e-infrastructure index shows that one of the key factors that impacts or limits e-infrastructure development is the lack of computers. Computer penetration is still very low in MENA countries because many people still cannot afford to buy computers. Therefore, the government should initiate programs to support computer use through the distribution of low-price computers to allow more people to gain access to computers. Also, import taxes on ICT goods should be reduced.

8.8 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 indices.

The first index is the nonparametric e-infrastructure index. It is based on the normalized human development index. Unlike the 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 indices ranks differ only slightly.

Besides, based on these two e-infrastructure indices, we analyzed the heterogeneity of the e-infrastructure between countries, regions, and over time. Hereby, we put a special focus on Middle East and North Africa (MENA) countries and OECD countries. The results show heterogeneity by region (i.e., economic region). For instance, the non-European OECD countries as an economic region perform quite well in comparison with other regions including the European OECD countries region, Middle East, and North Africa. The low rank of some countries is to some extent linked to their economic condition. Given the close relationship between e-infrastructure level and their GDP, poor countries from MENA have low ranks but some MENA countries, which belong to the Gulf Cooperation Council (GCC), outperformed a few OECD countries.

With respect to country heterogeneity, the results show that the high-ranked countries share similar patterns in various index component distributions. However, we found no evidence to suggest that if a country is performing well in one component, it will also perform well in other components.

The analysis over the time period of 8 years (2000–2007) showed that the two indices develop differently. The nonparametric index shows a decreasing pattern while the parametric index an increasing pattern. This is consistent with our expectations. The difference is attributed to the estimated weight heterogeneity assigned to different indicators in the parametric case. Therefore, the parametric e-infrastructure index is preferable.

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