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E-Government readiness index: A methodology and analysis

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ABSTRACT

E-Government has received significant attention as digital technologies transcend private businesses and serve as a basic source of transformation in government functions. One most notable project is the United Nations Public Administration Network (UNPAN) that assesses the e-Government readiness of the 192 member nations according to a quantitative composite index involving website assessment, telecommunication infrastructure, and human resource endowment. However, the UNPAN index, though rich in depth and breadth of data collection, relies on a method that is a simple mathematical average of the values of the variables measured. This paper revisits the UNPAN index and proposes alternative indices based on principal components analysis (PCA). Using the UNPAN survey data, four different versions of the index are presented and the resulting rankings of the nations are examined *vis-à-vis* the existing ranking. The theoretical and policy implications of the proposed methodology and its results are discussed.

1. Introduction

The key objective of our paper is to address the scope and constitution issues of e-Government readiness indices using methodological tools. More specifically, we methodically examine the e-Government readiness index maintained by United Nations' Department of Economic and Social Affairs (UNDESA), to address the questions of what specific elements should be included in and how the constitutive elements should influence the indices that measure and track e-Government readiness. Using complementary methodological approaches, we propose to address the issues of scope and constitution by developing alternative indices. We compare and contrast the alternative indices developed in this paper with each other, and also with the UNPAN index.

The use of information technology to govern has increasingly been the focus of several nations in the last few decades. Broadly termed electronic governance or e-Governance, it is an overarching concept that represents the use of information and communication technologies (ICTs) for delivering services to citizens as well as for orchestrating intra-government functions (Sheridan & Riley, 2006). Governments and policy making entities across nations have undertaken initiatives to formalize and exploit the role of ICTs in enabling and delivering governance functions. Concurrent with the policy initiatives, academic interest in the topic has grown and research has explored various constitutive elements of e-Governance, and the nature of adoption and impacts of e-Governance projects (Davison, Wagner, & Ma, 2005; Grant & Chau, 2005; Grönlund & Horan, 2004).

In this paper we focus on e-Government readiness that represents a particular area of policy-making and research within the broader umbrella of e-Governance initiatives. e-Government readiness primarily assesses the extent to which governments or economies are equipped to deliver various governmental services online and exploit ICT for internal functioning of the government (Al-Omari & Al-Omari, 2006; UNDESA, 2008). Multiple initiatives, undertaken by international organizations, consulting firms, and academic investigators, have sought to measure and operationalize the various aspects of readiness. While multiple projects aimed at measuring readiness have enriched the debate, it has also given rise to the question of convergence and consistency. Critics have argued that individual studies, motivated and initiated by specific stakeholders, focus on divergent sets of factors and are tied to specific contexts (Ojo, Janowski, & Estevez, 2007). For example, some studies focus on specific regions like Europe (Bannister, 2007; Ojo et al., 2007), and other studies have progressively modified scale-items over the years (Ojo et al., 2007), making comparisons of indices across time and geography somewhat difficult. Hence, as research on measuring e-Government readiness has gained recognition, the concept itself has become somewhat fragmented. Given the fragmented nature of e-Government readiness assessment, critiques have called for a more focused understanding of e-Government readiness (Bannister, 2007; Ojo et al., 2007).

The call for a more universal and consistent view of e-Governance readiness has alerted us to three key issues that characterize the existing efforts. First, what can ideally be thought of as constituting e-Government readiness when it comes to the scope of assessment

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and the selection of indicators? Across studies, the nature and number of variables used as measurement items have differed substantially, reducing scopes of cross-comparisons or development of a focused understanding of e-Government readiness. Second, how might individual variables contribute toward the overall indices, for which there needs to be comprehensive justification? Evidently, not all facets of technology can be considered equally important, and hence, the basis for weighting the contribution of individual elements toward the overall indices has varied significantly. Finally, from an implementation viewpoint, will the indices be suitable for certain users given that the indices have often been context specific? The specific settings and assumptions used in constructing the indices may require matching the indices with appropriate purposes.

The critical gaps outlined above need both conceptual and empirical examination. From a strictly conceptual point of view, one can attempt to redefine and streamline the concept and constitutive measures of e-Government readiness; from a rigorous empirical examination, one can also shed light on the existing indices and provide critical insights on their scope, constitution, and applicability. We choose to focus on the empirical route for multiple reasons. First, while significant resources have been expended to gather data on e-Governance readiness, there has been a singular lack of rigorous empirical examination of the acquired data (Ojo et al., 2007). The indices themselves have been based on straightforward and rudimentary combinations of constitutive items, and no systematic evaluation of the items, their inter-relations, or their contributions toward the overall indices has taken place. Additionally, there has been little examination done to validate the scales as inter-index relationships, as predictive instruments, or as covariates of other critical variables. Second, while re-conceptualizing, commissioning, and executing a new index study would need significant investments, an empirical examination of the index would attract infinitesimal additional cost. Finally, through an inductive approach, results of an empirical examination can help us develop alternative theoretical perspectives that would better inform future index conceptualizations.

We propose to address the issues of scope and constitution of indices by examining the internal structure of the data, and by exploiting the variances and co-variances of the items. We specifically build upon the UNPAN data and e-Government readiness index, and employ principal components analysis (PCA) to develop our indices. Our choice of methodology allows us to develop an empirical justification for including or excluding specific variables and also to create indices based on the relative contributions of specific variables towards the constitution of the index. Using specific assumptions and two different approaches, we develop four different indices and examine the resulting rankings of the nations *vis-à-vis* the ranking based on UNPAN index.

The rest of the paper is organized as follows: the next section reviews the relevant literature on e-Government readiness measures; the following section describes the existing method for e-Government readiness index used by UNPAN; the subsequent sections present our methodology, analysis, and results; and the final section discusses theoretical and policy implications and limitations, and future research directions.

2. Benchmarks for e-Government and e-Government readiness

E-Governance represents a paradigm wherein governments across economies strive to use ICTs, specifically the Internet, to deliver services to citizens and link intra-governmental functions. The enormous gains in process efficiencies and waste elimination that the private sector has enjoyed as a result of using ICTs have been viewed very favorably by policymakers who have intended to use technology for similar gains. Apart from motivations to increase efficiencies of government functions, it has been increasingly recognized that using technology is critical for empowering citizens and involving various stakeholders in governance (OECD, 2003, 2005; Shim & Eom, 2008; Tolbert & Mossberger, 2006; Yang & Rho, 2007). Within the field of e-Governance research, significant attention has been devoted to the concept of benchmarks and indices for assessing and measuring various e-Governance capabilities.

Significant diversity exists within the pool of initiatives meant to create the benchmarks and the stakeholders they cater to. Few of these benchmarks have been public-private initiatives, typically commissioned by governmental or inter-governmental bodies and executed by private consultants. Capgemini Ersnt & Young eEurope reports and related benchmarks meant to assess e-Governance capabilities of select European economies are such groups of benchmarks created through public–private partnerships (Cap Gemini Ernst and Young, 2005, 2006). Reports and benchmarks created by Accenture (Accenture, 2006), on the other hand, are largely private initiatives meant to serve policymakers as well as private investors interested in e-Governance. Further, Brown University's e-Government survey series, carried out by the Center for Public Policy at the university, represent academic research efforts to create e-Government assessments (West, 2004, 2005, 2006). Finally, United Nations' e-Government surveys, conducted annually since 2002, represent global inter-governmental efforts to assess the e-Government readiness at the national level (UNDESA, 2001, 2003, 2004, 2005, 2008, 2010). We do not provide a detailed review of individual benchmarking studies, as we specifically focus on indices meant to capture e-Government readiness. Comprehensive reviews of various benchmarking efforts can be found in the works of Bannister (2007), Jansen (2005), and Kunstelj and Vintar (2004).

E-Government readiness index represents a more focused line of research within the broad spectrum of electronic-governance literature. E-Government readiness index, along with the related research, has been motivated by the need to evolve a common measure to assess the preparedness of various nations to make the transformation to electronic governance. It has been conceived as a yardstick that allows nations to gauge their status relative to others attempting to implement electronic governance (Bannister, 2007; Ojo et al., 2007; UNDESA, 2008). It is also meant to alert policymakers to specific strengths and weaknesses that could be suitably addressed to deliver electronic governance. Additionally, the rankings have also come to be perceived as representative of national capabilities, and as a means to enhance national positions for purposes like attracting investments, gaining leverage in international negotiations, and motivating citizen adoption of electronic governance (Bannister, 2007; UNDESA, 2008). The UNPAN surveys commissioned by UNDESA specifically state that the purpose of assessing e-Government readiness is to gauge “how ready are member states to take advantage of the opportunity provided by advances in information technology?” (UNDESA, 2008). Apart from being a tool of comparative assessment, it is also meant to be a means to monitor the evolution of e-Government readiness over time for member states.

The critical differentiator between e-readiness indices and other related indices that track other aspects of e-Governance is the deliberate focus on preparedness, as opposed to proven e-Government capabilities. As an illustration, it can be noted that while UNPAN surveys also collect data on e-Government delivery capabilities in the form of e-Participation index, e-Participation itself is not an element of e-Government readiness. We focus on readiness, as it serves as the minimum common denominator for delivering electronic governance, and provides a baseline for comparing economies at diverse stages of e-Government evolution.

Within the limited field of e-Government readiness research, one can further note various strands. Readiness has been measured for a diverse set of functions and services, including such readiness measures as e-commerce, e-business, Internet diffusion, ICT development, digital access and connectivity, and information society among others (Bridges.org., 2005). While one might argue that certain indicators like readiness for e-commerce or e-business might not be the best representative features of e-Government, others nonetheless regard enablement of e-business or e-commerce as critical priorities. Such examples also highlight how e-Government readiness indices exhibit significant diversity and represent a variety of approaches to measuring readiness (Janssen, Rotthier, & Snijkers, 2004).

In an insightful analysis, Ojo et al. (2007) highlighted how three of the more accepted versions of e-readiness index – the UNPAN index, the Brown University survey, and the Accenture e-Government leadership series – have no substantive overlap in terms of content and measurement items. Apart from significant variations in the constitutive items, they also found critical differences in the development of the indices in terms of weighting, and measuring the contributions of individual elements. Further, their analysis indicated only a moderate correlation between the indices. More importantly, however, even within the UNPAN index they found that not all constitutive elements contribute equally toward the overall index. The UNPAN team acknowledges the concerns with index composition and states that "although methodological work on the UN e-Government survey has helped elucidate some of the issues in e-Government measurement, there is no formal agreement on a common international framework. There is also no single view of how such indicators should be designed so that they remain relevant and practical over time" (UNDESA, 2010). The key fundamental issues with a readiness index, as with any other composite index, are related to the choices of constitutive items for the index and the relative contribution of the items toward the index score. Largely, both the issues of scope and constitution – defined, respectively, as the choice of items to be included and the weights to be allocated to individual items – have been repeatedly cited by the critics of the e-Government readiness index as key drawbacks of the collective research stream (Bannister, 2007; Jansen, 2005; Ojo et al., 2007).

The resolutions of scope and constitution issues, and by extension the problem of context specificity of indices, have been principally addressed along two key dimensions. From a conceptual or theoretical point of view, there have been attempts to streamline the notion of e-Government readiness by redefining the key factors constituting readiness. Such attempts have sought to identify common elements across benchmarks, establish novel categorizations for prior and potential readiness factors, or have established fresh perspectives for defining readiness. Jansen's (2005) proposal to assess readiness as a composite of democratic, service, and administrative capabilities, or Kunstelj and Vintar's (2004) sophisticated model to measure governmental e-services are notable works that have sought to conceptually redefine the e-Government readiness indices. On the other hand, a relatively under-researched alternative to address the criticisms is to subject the indices to rigorous methodological examinations. Within the methodological stream, there can be rigorous evaluations of inter-index correlations, evaluation of item contribution toward indices, evaluation of indices in terms of predictive power on relevant variables, or efficacy of indices in creating relevant groupings of nations. Barring a few notable works (Ojo et al., 2007), there has been not much significant empirical evaluation of indices or their components.

For multiple reasons we choose to focus on the empirical alternative to address some of the pertinent criticism of indices. First, while conceptual refinements and alternative theoretical frameworks for redefining indices are critical, the attendant costs to implement the new measures and collect data can be prohibitive. With barriers to implementation and data collection costs, alternatives frameworks would have little applicability. Further, in spite of significant resources being poured into collection of information, much less effort has been expended to rigorously analyze the gathered information. Many of the benchmarks are elementary combinations of constitutive items, without any fundamental methodological or even theoretical bases for creation of the benchmarks. Additionally, while costs of gathering new data based on newly formed indices can be significant, costs of methodological analysis are infinitesimal. Moreover, one needs to validate the merits and properties of information already collected before proceeding to collect additional information. Finally, empirical examination could inductively lead the way to alternate theories and concepts of benchmarks. As Ojo et al. (2007) demonstrated, core indicators could be isolated from existing benchmarks, or categories of nations can be evolved through empirical examination of benchmarks.

In this study, we focus on the UNPAN index and employ PCA to specifically address the key scope and constitution issues related to benchmarks. The UNPAN data have been collected by UNDESA since 2002. The choice of UNPAN data in our research is primarily dictated by the fact that it has one of the widest coverage of nations and is one of the most current records of e-Government assessment. The Brown University survey, while comparable in scope to UNPAN, records 2006 as the year of its most recent data collection.

Our empirical assessment of the UNPAN data seeks to explore both constitution and scope issues. From the constitution point of view, we specifically explore four related questions. First, we explore whether there are significant differences across the items in their contributions toward the overall index. We further ascertain whether the specific sub-indices, as used within UNPAN survey, are equally responsible for the constitution of the overall index. And finally, we evaluate the contribution of constitutive items from two individual sub-indices: telecom infrastructure and human capital. To evaluate the scope questions, we primarily evaluate the correlations between various sub-indices on the readiness index. To address the issue of scope or what to measure, we study the correlations between select sub-indices, focusing on specific aspects of readiness. The correlations allow us to infer whether focusing on any specific aspect of readiness is materially different from focusing on other aspects of readiness.

2.1. UNPAN survey and methodology

The UNPAN e-Government readiness index is part of an effort by the UNDESA to document and assess the use of technology by national governments. The broader goal of the survey, commissioned annually since 2002, is to assess how national governments are ushering in efficiencies in delivering pubic services while streamlining the intra-governmental processes at the same time (UNDESA, 2008). The recent surveys focus on both the readiness of member nations to plan and implement critical ICT-based service deliveries as well as resultant citizen engagement in important governmental activities. Given the all-encompassing nature of the effect that ICT can have, the survey envisages ICT as ushering in "connected governance" that increases efficiencies of intra-governmental linkages, resulting in better service delivery and enhanced citizen participation in governance.

In specific terms, the survey measures e-Government readiness index and e-Participation index. The basic structure behind the e-Government readiness index has remained the same, although the methods for calculating some of its sub-indices have changed over the past few years. For example, in the 2005 e-Government readiness report (UNDESA, 2005), the telecommunication infrastructure index, which defines a country's ICT infrastructure capacity, was calculated as a composite index of six components (i.e., PCs, Internet users, telephone lines, online population, mobile subscribers, and TVs) with equal weights. In the 2008 UN e-Government survey (UNDESA, 2008), however, the telecommunication infrastructure index was based on only five components (i.e., Internet users, PCs, cellular phones, main telephone lines, and broadband), again with equal weights, but replacing online population and TVs with broadband. In our study, we use the data from the 2008 survey. The latest survey of 2009 indicates that, while the Web measure index has been repositioned as the online service index and some questions for assessing the Web measure index have been refined, "the methodological framework for the … index has remained consistent [with the past surveys]" (UNDESA, 2010).

The composite e-Government readiness index (denoted in this paper by *e-GRI*) is constructed using a hierarchical structure. Three sub-indices – telecommunication infrastructure index (denoted in this paper by $I_{TelInfra}$), the human capital index (denoted by I_{HC}), and the Web measure index (denoted by I_{Web}) – are used to form the composite *e-GRI* index. For calculating the *e-GRI*, all three sub-indices are allocated equal weights. Further, the sub-index of telecommunication infrastructure taps into the extent and reach of the physical communications infrastructure, and uses the numbers of PC (denoted by I_{PC}), cell phone (I_C), Internet (I_I), telephone (I_T), and broadband (I_B) users to calculate the index value. All the five index elements are equally weighted within the telecom infrastructure index. The human capital index taps into the general literacy and educational levels of the citizens, and uses percentages of adult literacy rate (denoted by I_{AL}) and the combined primary, secondary and tertiary gross enrolment ratio (denoted by I_{GE}) for index calculation. Unlike the telecommunication infrastructure index, however, the human capital index allocates two-thirds of the total weight to adult literacy and only one-third of the total to gross enrolment. Finally, the Web measure index is a composite measure of the presence or absence of comparable online functionalities provided to the public across member nations. A number of functionalities, grouped into five hierarchical stages, are assessed through the survey. The stages, ranging from basic online presence to comprehensive connected service delivery, are represented as emerging, enhanced, interactive, transactional, and the connected stages of Web-based service delivery.

It must be noted that the weighting scheme applied to the three major e-Government readiness sub-indices, as well as their elements, were chosen on the basis of their assumed contribution toward the indices. One can argue that the contributions of the sub-indices toward the overall index, as well as the contribution of the individual variables toward the sub-indices, can be substantively different when subjected to more rigorous methodological examination. As Ojo et al. (2007) demonstrated, when evaluated in terms of variability exhibited by individual elements, only seven of the sixteen elements were found to exhibit significant variability. We further refine this approach by going beyond measuring variability of individual elements, and actually measuring their contributions toward the overall variability of the composite index. Our approach on the choice of e-Government readiness sub-indices as well as their weights to be assigned is based purely on the analysis of the internal structures of the data and does not preclude the use of any pre-determined criteria for inclusion of any sub-indices.

3. Proposed methodology

The PCA technique has traditionally been used by practitioners to transform a large set of correlated variables into a smaller set of uncorrelated variables, called the principal components, which account for most of the variation in the original set of variables. Since the principal components are linear combinations of the original variables with mathematically determined characteristic vectors of the covariance (or correlation) matrix representing weights, it can be argued that PCA resolves the problems inherent in the arbitrary assigning of weights. The first principal component accounts for the largest proportion of variation in the original set of variables. The second principal component captures the largest proportion of variation, which is not accounted for by the first principal component, and so on. For a set of *k* variables, a maximum of *k* principal components can be extracted. However, if the *k* variables are highly correlated, only a few principal components capture most of the variation in the original set of variables. The proportion of variation attributed to a particular principal component is obtained by dividing the associated characteristic root by the sum of all characteristic roots (Hair, Black, Babin, Anderson, & Tatham, 2006; Morrison, 1967).

Recently, PCA has also served as a useful tool for selecting a few variables among a wider set of correlated variables. The technique used in the present paper is PCA method B4, which is described by Jolliffee (1972, p. 164; 1973, p. 22), and recommended by Jolliffee (1972, p. 168) in cases where retention of the best subsets of variables is considered important. Essentially, the method involves first selecting the variable that has the highest correlation with the first principal component. This is followed by the variable that has the highest correlation with the second principal component, where the second stage selection process is limited only to those variables that are discarded in the first stage selection process. This procedure is continued until the required number of variables has been selected. Jolliffee (1972, p. 171) recommends that the number of variables to be selected be equal to the number of principal components associated with characteristic roots of the correlation matrices which are greater than 0.70.

The data used in this study is based on the UN global e-Government survey (UNDESA, 2008), which assesses and ranks the e-Government readiness of 192 UN member states. The data is available at the United Nations e-Government Readiness Knowledge Base (UNKB), created by the Division for Public Administration and Development Management (DPADM) of UNDESA, for research, education and planning purposes. For our PCA methodology, we will use two different approaches, successive and simultaneous. The notations used to present these two approaches are summarized in Table 1.

3.1. Successive approach

With the successive approach, optimal weights for components of each major sub-index are determined first and then used for determining optimal weights for the three major sub-indices:

$$e{-}GRI = \xi_{TelInfra} I_{TelInfra} + \xi_{Web} I_{Web} + \xi_{HC} I_{HC}$$

$$\begin{aligned} \text{where } & I_{TelInfra} = \beta_I I_I + \beta_{PC} I_{PC} + \beta_C I_C + \beta_T I_T + \beta_B I_B, \\ & _{IHC} = \phi_{AL} I_{AL} + \phi_{GE} I_{GE}, \\ & \xi_{TelInfra},\ \xi_{Web},\ \text{and } \xi_{HC} \text{ are weights associated with components of } e{-}GRI, \\ & \beta_I, \beta_{PC}, \beta_C, \beta_T,\ \text{and } \beta_B \text{ are weights associated with components of } I_{TelInfra}, \\ & \phi_{AL} \text{ and } \phi_{GE} \text{ are weights associated with components of } I_{HC}, \\ & \text{all indices are on a scale of 0 to 1, and the sum of each set of weights equals 1.} \end{aligned} \tag{1}$$

The first step is to determine the optimal weights (i.e., β_I, β_{PC}, β_C, β_T, and β_B) associated with the five telecommunication infrastructure

Table 1
Description of notation.

Notation	Description
$I_{TelInfra}$	Telecommunication infrastructure index
$SI_{TelInfra}$	A simplified version of the telecommunication infrastructure index
I_{Web}	Web index
I_{HC}	Human capital index
SI_{HC}	A simplified version of the human capital index
e-GRI(UN)	The existing e-Government readiness index calculated by the United Nation
e-GRI(1F)	A full version of the e-Government readiness index based on the successive approach
e-GRI(1S)	A simplified version of the e-Government readiness index based on the successive approach
e-GRI(2F)	A full version of the e-Government readiness index based on the simultaneous approach
e-GRI(2S)	A simplified version of the e-Government readiness index based on the simultaneous approach

components for the construction of a new telecommunication infrastructure index (i.e.,$I_{TelInfra}$ defined in Eq. (1)). Evidence of a strong positive correlation among all the components of the telecommunication infrastructure index is apparent from Table 2, justifying the use of PCA and variable reduction.

Bartlett's test of sphericity, which indicates the presence of nonzero correlations, shows that the correlations are significant at the 0.001 level. Further, the overall value of the MSA (see Hair et al., 2006), which looks not only at the correlations between variables, but also at their patterns, is 0.895, which falls in the acceptable range (above 0.5). Each of the variables also exceeds the threshold MSA value (0.5), indicating that the set of variables meets the preconditions for PCA. The associated characteristic roots and vectors of the correlation matrix of the five telecommunication infrastructure components are reported in Table 3. It can be seen from the entries in the table that the first principal component accounts for approximately 83 percent of the variation in the five variables. The first two principal components account for approximately 91% of the variation in the five variables, and all five principal components obviously account for 100% of the variation in the five variables. Clearly, the first principal component contains most of the statistical information embedded in the five variables constituting the telecommunication infrastructure index.

The values of the characteristic vector associated with the first principal component of the five telecommunication infrastructure index variables are reported in Table 3. After rescaling the reported vector, to ensure that values of the characteristic vectors sum to unity, the first principal component $I_{TelInfra}$ could be computed as:

$$I_{TelInfra} = 0.21I_I + 0.20I_{PC} + 0.18I_C + 0.20I_T + 0.21I_B \quad (2)$$

One notable feature of Eq. (2) is that the first principal component weights are highest for Internet and broadband and lowest for cellular phones. Furthermore, the first principal component weights attached to the five variables in $I_{TelInfra}$ are not exactly equal, but they are somewhat consistent with and support the current practice of an equal weighting scheme adopted by UNPAN in its 2008 report (UNDESA, 2008).

The second step in the successive approach is to determine the optimal weights (i.e., ϕ_{AL}, ϕ_{GE}) associated with the two human capital components for the construction of a new human capital index (i.e., I_{HC} defined in Eq. (1)). Bartlett's test indicates that the correlations are significant at the 0.001 level. The overall value of the MSA as well as each of the two variables exceeds the threshold MSA value (0.5). The values of the components, reported in Table 4, show that the human capital index could be computed after normalization as

$$I_{HC} = 0.5I_{AL} + 0.5I_{GE} \quad (3)$$

It is worthwhile to note that the equal weights assigned to the two human capital components are not consistent with and thus do not support the UNPAN's current practice of using different weights, 2/3 and 1/3, for adult literacy and gross enrollment, respectively.

Table 2
Pearson's correlation matrix of the five components constituting the Infrastructure Index.

	Internet index	PC index	Cellular index	Telephone line index	Broadband index
Internet index	1.000				
PC index	0.852	1.000			
Cellular index	0.739	0.647	1.000		
Telephone line index	0.854	0.813	0.719	1.000	
Broadband index	0.857	0.874	0.659	0.812	1.000

All correlations are significant at the 0.01 level (2-tailed).

Table 3
Results of PCA of the five telecommunication infrastructure sub-indices.

	Principal component				
	First	Second	Third	Fourth	Fifth
Characteristic root	4.140	0.417	0.191	0.129	0.124
% of variance explained individually	82.798	8.334	3.812	2.581	2.475
% of variance explained cumulatively	82.798	91.132	94.944	97.525	100.000
Characteristic vectors					
Internet index	0.229	−0.081	−0.172	−2.055	−1.362
PC index	0.223	−0.572	0.719	1.626	−1.328
Cellular index	0.198	1.340	0.599	0.372	0.145
Telephone line index	0.223	−0.014	−1.909	0.683	0.556
Broadband index	0.224	−0.519	0.834	−0.528	2.033
Correlation coefficient with					
Internet index	0.948	−0.034	−0.033	−0.265	−0.169
PC index	0.924	−0.238	0.137	0.210	−0.164
Cellular index	0.820	0.559	0.114	0.048	0.018
Telephone line index	0.925	−0.006	−0.364	0.088	0.069
Broadband index	0.927	−0.216	0.159	−0.068	0.252

The third and last step in the successive approach is to determine the optimal weights ($\xi_{TelInfra}$, ξ_{Web}, ξ_{HC}) associated with the three major components for the construction of a new e-Government readiness index (*e-GRI*). We denote the index we develop using the successive approach by *e-GRI* (1F), which simply refers to the first approach, full version, where all of the sub-components are retained. Bartlett's test applied to this set of data indicates that the correlations are significant at the 0.001 level with the overall MSA value of 0.703. Each of the three variables also exceeds the threshold MSA value (0.5), indicating that the set of variables meets the preconditions for PCA. The values of the characteristic vector associated with the first principal component of the three main sub-indices, reported in Table 5, show that *e-GRI* (1F) after normalization can be computed as

$$e{-}GRI(1\mathrm{F}) = 0.35I_{TelInfra} + 0.32I_{Web} + 0.33I_{HC} \quad (4)$$

As can be seen from Eq. (4), the weights assigned to the three major component indices are almost equal, supporting the UNPAN's equal weighting scheme for the three components.

Further applying the basic principles of PCA, we identify whether one, all, or some of the components of $I_{TelInfra}$ need to be retained for final calculations. It is easy to verify from the entries in Table 3 that only one characteristic root, derived from the correlation matrix of the five sub-indices of $I_{TelInfra}$, is greater than 0.70, suggesting that only one of these components needs to be retained for the purpose of computing a simpler $I_{TelInfra}$, which is denoted by $SI_{TelInfra}$. Since the decision as to which of the five sub-indices should be retained requires information on the correlations (or loadings) between the variables and the principal components, these correlations are also

Table 4
Results of PCA of the two human capital sub-indices.

	Principal component	
	First	Second
Characteristic root	1.796	0.204
% of variance explained individually	89.825	10.175
% of variance explained cumulatively	89.825	100.000
Characteristic vectors		
Adult literacy	0.528	−1.567
Gross enrollment	0.528	1.567
Correlation coefficient with		
Adult literacy	0.948	−0.319
Gross enrollment	0.948	0.319

Table 5
Results of PCA of the three major components of *e-GRI*.

	Principal component		
	First	Second	Third
Characteristic root	2.286	0.442	0.272
% of variance explained individually	76.214	14.724	9.062
% of variance explained cumulatively	76.214	90.938	100.00
Characteristic vectors			
Telecom. infrastructure index	0.397	−0.101	−1.528
Web measure index	0.371	1.121	0.691
HR index	0.377	−0.998	0.931
Correlation coefficient with			
Telecom. infrastructure index	0.909	−0.045	−0.415
Web measure index	0.848	0.495	0.188
HR index	0.861	−0.441	0.253

reported in the bottom row of Table 3. It can be seen from the entries in the table that the Internet index (I_I) has the highest correlation (i.e., r = 0.948) with the first principal component. Accordingly, it can be concluded, based on the aforementioned selection criterion, that Internet is the best choice. Thus, $SI_{TelInfra}$ can be computed basically as I_I (or Internet index).

In regard to the formation of the human capital index, Table 4 shows that only one characteristic root is greater than 0.70, suggesting that only one of the two sub-indices of I_{HC} be retained for the purpose of computing a simpler I_{HC}, which is denoted by SI_{HC}. Since both sub-indices have the same correlation (i.e., r = 0.948) with the first principal component, either can be chosen to represent a simpler form of the human capital index. Thus, SI_{HC} can be computed as either I_{AL} (adult literacy) or I_{GE} (gross enrollment). The final step in our successive approach is to determine the optimal weights associated with the three major components for the construction of a simpler e-Government readiness index, which is denoted by *e-GRI* (1S). Since the weights in the simpler version *e-GRI* (1S) are different from the weights in the full version *e-GRI* (1F), we denote the weights associated with the three major component indices of *e-GRI* (1S) by $\theta_{TelInfra}$, θ_{Web}, and θ_{HC}.

As shown in Table 5, only one component has a characteristic root greater than 0.70, suggesting that only one of the three major component indices be retained for computing *e-GRI* (1S). It can be seen from the entries in the table that the telecommunication infrastructure index (i.e., $SI_{TelInfra}$) has the highest correlation (i.e., r = 0.909) with the first principal component. Note that it has been shown that $SI_{TelInfra} = I_I$. Accordingly, *e-GRI* (1S) can be computed as

$$e-GRI(1S) = SI_{TelInfra} = I_I \tag{5}$$

3.2. Simultaneous approach

Our second approach to computing the *e-GRI* is the simultaneous approach. In this approach, we determine the optimal weights of the eight individual components simultaneously using PCA. Table 6 reports the values of Pearson's product moment correlation coefficients (r). Bivariate correlations among all the eight components are quite strong. Bartlett's test also shows that the correlations are significant at the 0.001 level with the overall MSA value of 0.912, which falls in a higher side of the acceptable range (above 0.5). Each of the eight variables also exceeds the threshold MSA value (0.5), indicating that the set of variables meets the preconditions for PCA.

The values of the characteristic vector associated with the first principal component of the eight sub-indices, reported in Table 7, show that *e-GRI* (2F) after normalization can be computed as

$$e-GRI(2F) = 0.13I_I + 0.13I_{PC} + 0.12I_C + 0.13I_T + 0.13I_B + 0.12I_{Web} + 0.11I_{AL} + 0.13I_{GE}. \tag{6}$$

One interesting note in Eq. (6) is that although the weights of the eight sub-indices assigned to the first principal component are not equal, there are no sizable differences. Thus one may use, for practical purposes, an equal weighting scheme by assigning a weight of 0.125 to each of the eight sub-indices.

It can be verified from the entries in Table 7 that two characteristic roots, derived from the correlation matrix, are greater than 0.70, suggesting that only two of the eight sub-indices be retained for the purpose of computing a simpler *e-GRI* using this approach, which is denoted by *e-GRI* (2S). It can be seen from the entries in the table that both the Internet index (I_I) and the telephone line index (I_T) have the highest correlation (r = 0.922) with the first principal component. In this case, either one can be selected. The decision as to which of the seven sub-indices should be retained as the second variable requires identifying a variable which has the highest correlation with the second principal component. Accordingly, it can be concluded, based on the aforementioned selection criterion, that the adult literacy is the best choice. The values of the characteristic vector associated with the first principal component of Internet index and the adult literacy index for a simpler e-Government readiness index are reported in Table 8. Therefore, *e-GRI* (2S) can be computed as

$$e-GRI(2S) = 0.5{*}I_I + 0.5{*}I_{AL}. \tag{7}$$

4. Discussion and implications

The results obtained in the previous section provide critical insights regarding both the scope and constitution of the *e-GRI*. We first discuss the issue of constitution, highlighting the key findings related to how components of the index contribute toward the overall index. We must emphasize here that we basically treat the coefficient values for variables within given principal components as their weights or relative contributions toward index composition.

Table 6
Pearson's correlation matrix of the eight sub-components constituting the *e-GRI*.

	Internet	PCs	Cellular	Telephone lines	Broadband	Web measure	Adult literacy	Gross enrollment
Internet	1.000							
PCs	0.858	1.000						
Cellular	0.747	0.662	1.000					
Telephone lines	0.862	0.833	0.767	1.000				
Broadband	0.863	0.919	0.672	0.825	1.000			
Web measure	0.713	0.703	0.677	0.688	0.709	1.000		
Adult literacy	0.556	0.480	0.610	0.639	0.440	0.549	1.000	
Gross enrollment	0.716	0.632	0.733	0.753	0.635	0.698	0.801	1.000

All correlation is significant at the 0.01 level (2-tailed).

Table 7
Results of PCA of the eight e-Government readiness sub-indices.

	Principal component							
	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eight
Characteristic root	5.962	0.842	0.368	0.322	0.164	0.140	0.127	0.076
% of variance explained individually	74.522	10.522	4.598	4.019	2.051	1.753	1.586	0.950
% of variance explained cumulatively	74.522	85.043	89.642	93.661	95.712	97.465	99.050	100.000
Characteristic vectors								
Internet index	0.155	−0.226	−0.275	−0.075	−0.427	−1.234	2.063	−0.144
PC index	0.149	−0.412	−0.251	0.406	0.456	1.060	−0.164	−2.442
Cellular index	0.143	0.149	0.177	−1.538	0.362	0.680	0.077	−0.084
Telephone line index	0.155	−0.073	−0.506	−0.114	0.352	−1.569	−1.744	0.135
Broadband index	0.149	−0.447	−0.151	0.266	−0.185	1.044	−0.135	2.586
Web measure index	0.139	−0.007	1.452	0.382	0.404	−0.484	−0.112	0.015
Adult literacy index	0.121	0.730	−0.400	0.552	1.195	0.327	0.558	0.486
Gross enrollment index	0.144	0.455	0.013	0.197	−1.955	0.361	−0.459	−0.473
Correlation coefficient with								
Internet index	0.922	−0.191	−0.101	−0.024	−0.070	−0.173	0.262	−0.011
PC Index	0.890	−0.347	−0.092	0.131	0.075	0.149	−0.021	−0.186
Cellular index	0.850	0.126	0.065	−0.495	0.059	0.095	0.010	−0.006
Telephone line index	0.922	−0.062	−0.186	−0.037	0.058	−0.220	−0.221	0.010
Broadband index	0.887	−0.376	−0.056	0.085	−0.030	0.146	−0.017	0.197
Web measure index	0.831	−0.006	0.534	0.123	0.066	−0.068	−0.014	0.001
Adult literacy index	0.723	0.615	−0.147	0.178	0.196	0.046	0.071	0.037
Gross enrollment index	0.860	0.383	0.005	0.063	−0.321	0.051	−0.058	−0.036

4.1. Index constitution

If we evaluate *e-GRI* (1F), which is a weighted combination of the sub-indices of telecom infrastructure, Web measure, and human capital, several conclusions come to the fore. First of all, as determined by the internal structure of the data, *e-GRI* (1F) demonstrates that all the three sub-components of the index contribute almost equally toward the index. Although the finding parallels the assumption of UNPAN, it now provides an important empirical underpinning to that assumption. The results provide more useful information when *e-GRI* (1F) is viewed alongside *e-GRI* (2F). Note that *e-GRI* (2F) indicates all the individual elements of the index and just not the three key sub-indices contribute almost equally toward the overall index.

The results as represented by *e-GRI* (1F) and *e-GRI* (2F) add in several ways to our understanding of the constitution of the UNPAN index. As envisaged in the UNPAN survey, the index has been conceived as a composite of three sub-indices each contributing equally to the index. This approach not only leaves open the question of justifying the equal weighting scheme as discussed above, but also the question of individual contributions of the survey items when not grouped under specific sub-indices. Our results indicate that if one were to ignore the grouping of the individual items under the three main sub-indices, and consider each of them individually, all of them would contribute equally toward the index. Hence, even in the absence of higher level groupings indicated by the three sub-indices, one can safely conclude that all survey items are equally critical for computing the index. This result also contradicts the findings of Ojo et al. (2007) who argue in favor of only select items being core, and others being non-core. Our results indicate that all items are indeed core and important. It has to be noted here that Ojo et al. (2007) considered the five specific stages of Web measure index as five individual indicators, while we consider only one composite Web measure value. This is primarily because stages of the Web measure are hierarchical and not constitutive elements of indices in the sense that five elements used for telecom-infrastructure are. While high correlations can be noted between the components of the human capital and telecom-infrastructure sub-indices, the same cannot be said about the five stages of the Web measure index.

Finally, on the constitution issue, we examine the telecom-infrastructure and human capital sub-indices. As Eq. (2) reveals, the five components of telecom infrastructure make almost comparable contributions, and this finding is in line with UNPAN's assumption. As Eq. (3) demonstrates, however, components of the human capital index – gross enrollment and adult literacy – make equal contributions, contradicting the UNPAN's allocation of weights. In summary, as revealed by the internal structure of the data, all constitutive elements of the UNPAN index are crucial and important for the index construction. This is true if one were to consider the individual variables in isolation, or the broad constructs of telecom-infrastructure, human capital, and Web measure as aggregates. Further, even for the key sub-indices of telecom infrastructure and human capital, the constitutive elements are all found to be equally important.

Table 8
Results of PCA of the two e-Government readiness sub-indices.

	Principal component	
	First	Second
Characteristic root	1.625	0.375
% of variance explained individually	81.261	18.739
% of variance explained cumulatively	81.261	100.000
Characteristic vectors		
Internet index	0.555	−1.155
Adult literacy index	0.555	1.155
Correlation coefficient with		
Internet index	0.901	−0.433
Adult literacy index	0.901	0.433

4.2. Scope of index creation

We next turn to examining the issue of scope as envisaged in the UNPAN data. As critics have routinely pointed out, what should or should not be included as measures of e-Government readiness is a moot point. We address the issue from an entirely empirical perspective. Variables or constructs that account for the biggest shares of the variances in the overall index are considered to be the core or key indicators. It has to be noted here that we apply fundamentally different criteria to address the scope and constitution issues. To determine constitution of an index, we relied on variable coefficients within specific principal components. On the other hand, we rely on explained variance as well as the correlation between the individual variables and given principal components to imply inclusion or exclusion of specific items from the index.

As explained in the foregoing section, one of the aims of PCA is to achieve parsimony without sacrificing valuable information. A way to achieve this is to retain the minimal number of variables that continue to explain significant variances. For *e-GRI* (1S), the first principal component not only explains almost 77% of the variations in the entire data-set, but telecom-infrastructure sub-index has a very high correlation of 0.909 with that particular principal component. Hence, telecom infrastructure emerges to be the one construct that ideally defines the scope of e-Government readiness. Further, applying the same principles, within the telecom-infrastructure construct we identify the Internet index or Internet connections per hundred users to most appropriately represent the scope of e-Government readiness. Further, examining *e-GRI* (2S) we find that two principal components explain cumulatively 85% of the variances in the overall data set, and the variables of Internet-connection and adult literacy have correlations of .90 and .62 respectively with the two principal components. Hence, according to *e-GRI* (2S) Internet connections per hundred users and adult literacy are two most important candidates to define the scope of e-Government readiness.

It must be noted here that when addressing the scope issue, we do not aim for comprehensiveness, but rather on the minimal set of factors that can explain the maximum amount of differences across nations. In other words, while several higher level capabilities sets nations apart in terms of readiness, a much smaller set of variables actually accounts for the bulk of the differences across nations. Hence, if one were to focus on the key differentiators affecting readiness of member states, at the expense of being comprehensive, one would choose Internet connection and adult literacy as the main variables.

4.3. Interpretation and comparison of indices

Next, we examine the relevance of the indices and the variations in rakings based on the new indices developed in this paper *vis-à-vis* the UNPAN index. Using the four versions, the index values are computed for each of the 192 member nations and the resulting rankings are examined *vis-à-vis* the ranking from the current UNPAN index. Table 9 shows the correlations between pairs of the existing and our four versions. The indices, *e-GRI* (1F), *e-GRI* (2F) and *e-GRI* (2S) have very high correlations (i.e., r = 0.9992, r = 0.9754 and r = 0.9340) with the existing UNPAN *e-GRI*. Not surprisingly, the correlation between *e-GRI* (1S) and other indices is just moderately high.

Table 10 shows the rankings of the top 40 countries of the e-Government readiness indices among the 192 nations studied based on the current UNPAN method and the four versions of the proposed method. One may see that the ranking based on *e-GRI* (1F) is quite similar to those based on the current one, i.e., *e-GRI* (UNPAN), as 38 countries have appeared on both lists. The ranking based on *e-GRI* (2F) is also quite consistent with both *e-GRI* (UNPAN) and *e-GRI* (1F) as 36 countries have made all three lists. However, there are sizable discrepancies in the top 40 countries between the full versions (i.e., *e-GRI* (1F) and *e-GRI* (2F)) and the simplified versions (i.e., *e-GRI* (1S) and *e-GRI* (2S)). The simplified versions share similar lists (i.e., 36 nations) and include unexpected nations such as Belarus, San Marino, and Brunei.

The four indices developed in this paper complement the existing UNPAN index and can be interpreted and used in complementary fashions. Table 11 provides a comparative assessment of all the four indices developed in this paper as well as the UNPAN index.

Our first index, *e-GRI* (1F), is closest in structure to the UNPAN index. This index can be designated as a *comprehensive sector-based index*, emphasizing that the index is based on the contribution of the three critical components or sectors responsible for e-Government readiness. Next, we designate *e-GRI* (2F) as the *comprehensive item-based index*, emphasizing that the index is based on equal weighting of all the elementary index items, and not on the broad sectors used to create the index. Both the sector-based and the item-based comprehensive indices are based on the entire set of variables and sectors used by the UNPAN survey.

UN member nations and policymakers can use these two indices under two specific assumptions. First, when the all the constitutive elements as used by UNPAN are thought to be indispensable for index calculation, and second, when all of them are assumed to be equally influential in affecting readiness. It is important to note here the distinction between the sector-based and item-based comprehensive indices. While the former emphasizes the sector as the main contributor of readiness, independent of how each sector is constituted, the later emphasizes the individual elements, independent of the sectors they are grouped into. If one emphasizes the sector, the contribution of the sectors becomes important, irrespective of the exact items and their related weights used within individual sectors. Hence, one might derive substantively different sets of indices while assuming the sectors to be equally important, owing to differences in weighting schemes used within the sectors. The difference between

Table 9
Pearson's correlation matrix of the existing and proposed *e-GRI*s.

	e-GRI(UN)	*e-GRI*(1F)	*e-GRI*(1S)	*e-GRI*(2F)	*e-GRI*(2S)
e-GRI(UN)	1.0000				
e-GRI(1F)	0.9992	1.0000			
e-GRI(1S)	0.8600	0.8696	1.0000		
e-GRI(2F)	0.9754	0.9801	0.9217	1.0000	
e-GRI(2S)	0.9340	0.9301	0.9040	0.9371	1.0000

Table 10
International rankings based on alternative *e-GRI* calculations.

Rank	*e-GRI* (UN)	*e-GRI* (1F)	*e-GRI* (1S)	*e-GRI* (2F)	*e-GRI* (2S)
1	Sweden	Sweden	Netherlands	Netherlands	Netherlands
2	Denmark	Denmark	Norway	Sweden	Norway
3	Norway	Norway	New Zealand	Denmark	New Zealand
4	Netherlands	Netherlands	Sweden	Norway	Sweden
5	USA	USA	Australia	Switzerland	Australia
6	Korea(Rep)	Korea(Rep)	Luxembourg	Canada	Luxembourg
7	Canada	Canada	Korea (Rep)	Korea(Rep)	Korea (Rep)
8	Australia	Australia	USA	USA	USA
9	France	France	Japan	Australia	Japan
10	UK	UK	Canada	UK	Canada
11	Japan	Japan	Iceland	Iceland	Iceland
12	Switzerland	Switzerland	Slovenia	Luxembourg	Slovenia
13	Estonia	Estonia	Liechtenstein	France	Liechtenstein
14	Luxembourg	Finland	Switzerland	Finland	Barbados
15	Finland	Luxembourg	Barbados	Japan	Switzerland
16	Austria	New Zealand	Denmark	Estonia	Denmark
17	New Zealand	Austria	Estonia	Israel	Estonia
18	Israel	Israel	Belarus	New Zealand	Belarus
19	Ireland	Ireland	Monaco	Austria	Monaco
20	Spain	Iceland	San Marino	Germany	San Marino
21	Iceland	Spain	UK	Liechtenstein	UK
22	Germany	Germany	Finland	Singapore	Finland
23	Singapore	Singapore	Austria	Ireland	Austria
24	Belgium	Belgium	France	Belgium	France
25	Slovenia	Slovenia	Italy	Slovenia	Italy
26	Czech Rep.	Monaco	Germany	Italy	Latvia
27	Italy	Italy	Latvia	Monaco	Germany
28	Lithuania	Czech Rep.	Jamaica	Spain	Belgium
29	Malta	Lithuania	Belgium	Czech Rep.	Spain
30	Portugal	Malta	Malaysia	Lithuania	Slovakia
31	Hungary	Portugal	Brunei	Portugal	Cyprus
32	UAE	Hungary	Spain	Andorra	Brunei
33	Poland	UAE	Cyprus	Barbados	Hungary
34	Malaysia	San Marino	Slovakia	Malta	Czech Rep.
35	Cyprus	Poland	Singapore	Cyprus	Malaysia
36	Latvia	Liechtenstein	UAE	Latvia	Ireland
37	Liechtenstein	Malaysia	Seychelles	Poland	Croatia
38	Ukraine	Cyprus	Antigua	Slovakia	Singapore
39	Slovakia	Latvia	Hungary	UAE	Andorra
40	Mexico	Ukraine	Czech Rep.	Hungary	Lithuania
:	:	:	:	:	:

Table 11
Index comparison.

	Comprehensive sector-based index e-GRI (1F)	Comprehensive item-based index e-GRI (2F)	Basic readiness index e-GRI (1S)	Core readiness index e-GRI (2S)	UNPAN index e-GRI
Correlation with existing UNPAN index	Very high	Very high	Moderately high	High	–
Scope of index creation	Three key sectors are necessary building blocks for readiness index: *telecom infrastructure*, *human resource*, and *Web measure*	Eight basic items are necessary elements for readiness index: penetration levels of *cell phones*, *broadband*, *telephone*, *Internet*, and *PCs* among the citizens; along with *adult literacy*, *gross enrollment*, and *Web measure*.	Penetration or intensity of *Internet use* is the key enabler of readiness	*Internet penetration* and *adult literacy* are main enablers of readiness	Three key sectors are necessary building blocks for readiness index: *telecom infrastructure*, *human resource*, and *Web measure*
Composition of index	*Main index:* All three sectors mentioned above must be equally weighted for index composition *Sub-indices:* All index elements for infrastructure and human resource must be equally weighted	All eight items mentioned above must be equally weighted for index composition	Only Internet use must be measured for index composition	Internet use and adult literacy should be equally weighted for index composition	*Main index:* All three sectors mentioned above must be equally weighted for index composition *Sub-indices:* While all index elements for infrastructure must be equally weighted, adult literacy must be weighted twice as much as gross enrollment for human capital
Implications for policymakers	Policymakers need to invest in and focus equally on building up the communication infrastructure, boost the human resource capabilities, and enhance governmental online capabilities to be e-Government ready. Further, all index-items within individual sectors must receive equal attention.	Policymakers should make all out investments to boost all the telecom infrastructure components including cell phones, Internet, broadband, and telephone connections, and also promote PC use, while simultaneously implementing measures to promote adult literacy and school enrolment, and undertaking enhancements of its online capabilities.	Policymakers must primarily ensure connectivity through Internet availability	Policymakers should primarily invest in enhancing Internet availability and increasing adult literacy rates	Policymakers need to invest in and focus equally on building up the communication infrastructure, boost the human resource capabilities, and enhance governmental online capabilities to be e-Government ready. Further, while all communication infrastructure components deserve equal attention, boosting adult literacy must receive priority over school enrolment.
Capital investment and resource mobilization needs for policymakers	Relatively much higher resource mobilization and capital investments are necessary for achieving all-encompassing e-Government preparedness.	Relatively much higher resource mobilization and capital investments are necessary for achieving all-encompassing e-Government preparedness.	Lowest levels of capital investment and resource mobilization needs	Relatively much lower levels of capital investment and resource mobilization needed	Relatively much higher resource mobilization and capital investments are necessary for achieving all-encompassing e-Government preparedness.
Efficacy	Index scores represent comprehensive and balanced preparedness levels, reflecting a robust and diverse telecom infrastructure, well developed online governmental services, and an educated citizenry capable of using the services on offer	Index scores represent comprehensive and balanced preparedness levels, reflecting a robust and diverse telecom infrastructure, well developed online governmental services, and an educated citizenry capable of using the services on offer	Index scores represent primarily the extent of Internet coverage	Index scores represent the extent of Internet coverage and adult literacy levels	Index scores represent comprehensive and balanced preparedness levels, reflecting a robust and diverse telecom infrastructure, well developed online governmental services, and educated citizenry capable of using the services on offer
Scope of use	Index more suited to countries at the higher end of the spectrum with established performance on technological and social indicators	Index more suited to countries at the higher end of the spectrum with established performance on technological and social indicators	Index more suited to measure either the basic preparedness of all nations, or the readiness levels of countries with lower recorded technological performance indicators.	Index more suited to measure either the basic preparedness of all nations, or the readiness levels of countries with lower recorded technological and social performance indicators.	Index more suited to countries at the higher end of the spectrum with established performance on technological and social indicators
Technological specificity	Very high. Since the index relies on use of specific communication technologies, it can be rendered irrelevant with	Extremely high. Since the index relies on use of specific communication technologies, it can be rendered irrelevant with	Very low. The index can remain relevant independent of the actual technology used, as it primarily taps into	Very low. The index can remain relevant independent of the actual technology used, as it primarily taps into Internet	Very high. Since the index relies on use of specific communication technologies, it can be rendered irrelevant with

Table 11 (*continued*)

	Comprehensive sector-based index e-GRI (1F)	Comprehensive item-based index e-GRI (2F)	Basic readiness index e-GRI (1S)	Core readiness index e-GRI (2S)	UNPAN index e-GRI
	the emergence of new technologies for accessing and relaying communication electronically. However, since it emphasizes the communication infrastructure and not the specific elements within, it can remain relevant through reconfiguration of the components of infrastructure.	the emergence of new technologies for accessing and relaying communication electronically.	Internet connectivity, irrespective of the technology used.	connectivity, irrespective of the technology used.	the emergence of new technologies for accessing and relaying communication electronically. However, since it emphasizes the communication infrastructure and not the specific elements within, it can remain relevant through reconfiguration of the components of infrastructure.

UNPAN and the sector-based comprehensive index developed in this paper is a case in point. They both consider the three sectors to be equally important. The human capital index in UNPAN uses twice as much weight for adult literacy as gross enrollment, whereas the sector-based comprehensive index uses exactly equal weights for both. The index of choice will depend on user priorities, but has to be based on the rationale and logic underlying each index.

For policymakers, the existing UNPAN index, as well the comprehensive sector and item based indices, have similar implications. They should prepare to enhance the state of telecom infrastructure, boost basic educational levels of citizens, and improve online offerings of governmental services all at the same time and with equal urgency. Additionally, the policymakers would also need to make substantial capital investments and mobilize a significant amount of resources if they seek to calibrate their preparedness levels using either the UNPAN index or the comprehensive sector and item-based indices. Evidently, the index scores on all the three indices represent broad based and comprehensive preparedness levels emphasizing at once the states of communication infrastructure, general educational levels, and availability of online governmental services. Given the comprehensiveness of the coverage as well as the investment needs, these indices might be more suited to countries ranking at the higher end of technological and social achievement indicators. It is also very important to note that all three indices can be highly sensitive to technological changes. As modes of accessing and delivering the Internet change rapidly over the next few years, the use of specific telecom indicators within the indices might render them irrelevant as technology evolves.

Further, we designate *e-GRI* (1S) as the *basic readiness index*, and *e-GRI* (2S) as the *core readiness index*. Both these indices use a much smaller set of variables compared to the UNPAN index. These two indices can be used when users choose to focus on the most important readiness differentiators. Further, the indicators can typically be used when data for a wider set of variables is not available for a particular user or a group of users. The indices will also prove very practical when information related to other variables is difficult to collect due to prohibitive costs.

For policymakers, the basic and core readiness indices have similar implications. Policymakers should focus on primarily making the Internet available, largely independent of the modes or specific technologies that are needed for providing the connectivity. Additionally, policymakers choosing to use the core readiness index should also focus on boosting adult literacy levels, without necessarily emphasizing the medium, like conventional schools and colleges, through which the citizens achieve literacy. Given the reduced scope of coverage as opposed to comprehensive indices, the investment levels and resource mobilization needs will also be much lower. The policymakers should be aware, however, that the scores on basic and core indices do not reflect comprehensive readiness, but primarily reflect adequate preparedness for initiating e-Governance. Given the reduced scope of coverage, these indices might be more suited to countries that are not at the highest levels of technological and social achievement indicators. However, these indices are especially well-suited to handle changes in technology and offer higher levels of flexibility to policymakers. Since the focus is on making the Internet available, through any possible means, the indices are not tied to any specific technology and hence the rankings based on these indices are less susceptible to technological changes. Hence, policymakers can choose to adopt the technology that seems more suited to their context. In Africa, for instance, in face of prohibitive investments and costs associated with legacy technologies, small business owners and individuals alike have extensively exploited the medium of cellular phones for business transactions.

4.4. Contributions, limitations, and future research

The UNPAN project encompasses an extensive data collection effort, particularly on the Web measure index due to the survey involved in obtaining the data for this component. This could be a bottleneck for the regular availability of the index as an indicator of e-Government progress. The proposed technique has traditionally been used by practitioners as a variable reduction procedure by transforming a large set of correlated variables into a smaller set of uncorrelated variables or principal components that account for most of the variation in the original set of variables. Our current study and the technique we apply here can have implications for similar index building exercises beyond the UNPAN index. As many local, provincial, and national governments embark on e-Government initiatives, our study provides some critical guidelines for index composition and application.

First, as our results demonstrate, empirical evaluation of the indices might be a necessary step to evaluate the efficacy of the index. While scope and constitution of the index can be theoretically or conceptually determined, whether or not they truly represent the observed phenomenon can be more appropriately ascertained through empirical evaluation. For example, though the UNPAN index assumed adult literacy twice as important as school enrollment, data collected from the target population showed both to be equally important. Second, as our findings highlight, it might be worthwhile to focus on capabilities of technology rather than technologies themselves. As technology evolves rapidly, any specific medium, or the technology artifact through which information is accessed, can quickly become irrelevant. For instance, with rapid increases in the capabilities of handheld devices, including PDAs and cell phones, a technology indicator like PC use becomes irrelevant with time. Hence, one should focus on the relevant capability, which is the ability to connect to the Internet in this case, rather than on the device which provides the capability. Third, building on the specific empirical results of this study, it can be recommended that policymakers should not emphasize the supply aspects of e-Government at the expense of nurturing the demand side. As our results show, variances in index values were largely accounted for by the infrastructure and human resource constructs than by the Web measure construct. The results imply that while governments can choose to rely on supply or push factors like creating superior online features and functionalities, the uptake of such services is critically dependent on the ability of the citizens to exploit the services and the infrastructure necessary to make those services widely available. Hence, it is important for policymakers to be attentive to the needs of delivery and absorption facilitators like educated citizenry and the underlying telecom infrastructure for ushering in e-Government.

This study has limitations which relate to two aspects of our analysis. The first aspect relates to the variables used in the development of the index. Our index development is based on the set of variables that are used in the UNPAN project. We believe that there may be other variables that are potential determinants of e-Government readiness. While our method primarily aims at providing empirical justification for the choice of the weighting schemes, it also inherits any limitation related to the completeness or scope of the variables included in the index development. Our study, however, provides opportunities for additional research and expanding the scope of variables that will further enhance the contribution of the proposed methodology. Based on our earlier arguments, we propose that expanding the scope of index items or constructs can follow two complementary paths. First, since the demand side factors are important, readiness measures should tap into accessibility and benefit factors including ease of use, ease of access, reliability of services, and usability, among others. Second, given the permanence of change in the technology sphere, policymakers must be prepared to constantly refresh the basket of technologies that create the information infrastructure and are incorporated in the index. Hence, it would require constant attention to new technology features like Web 2.0 and interactive capabilities, enhanced media capabilities, and evolving mobile or anywhere service capabilities, among others. If technology or infrastructure measures do no evolve over time, the indices can quickly lose relevance.

The second limitation relates to benchmarking of our results. Given that there are no other techniques available in the literature that could be used as benchmarks for our analysis and results, we cannot conclude that our indices are superior to the existing index. However, we would like to highlight that the proposed indices and the weighting scheme used to develop these indices are derived from the internal structures of the data. We believe that our methodology sets the stage for quantitative measurement techniques and analysis, and thus provides future research opportunities in e-Government research.

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