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Composite indices for the evaluation of a country's information technology development level: Extensions of the IDI of the ITU

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A B S T R A C T

A valid assessment of the development status of information and telecommunication technologies (ICT) at the country level is of vital importance because a nation's ICT achievement level is a significant driver of its socio-economic change. A widely used means for such assessments is the ICT Development Index (IDI) of the International Telecommunication Union (ITU). It is a composite measure, which generates country scores from the weighted addition of 11 indicators. Unfortunately, the IDI and many other proposals for similar composite measures suffer from two shortcomings. First, they take the index scoring as an end in itself and do not construe an index in a way which maximizes its capability to predict a specific outcome criterion that translates into socio-economic achievements of a nation. Second, individual indicator and sub-index weights are frequently subjective estimates or are based on inadequate quantitative measurement models. The present work addresses both issues. It applies partial least squares (PLS) structural equation modeling (SEM) to compute aggregation weights for the 11 individual indicators and the three sub-indices of the ITU's IDI in a way that the association between the modified IDI and a chosen socio-economic target criterion – gross domestic product per capita change – is maximized. Both formative and reflective measurement models are used in calculating target-related indicator and sub-index weights and resulting total modified IDI scores for 137 countries for 2012. Whereas indicator and sub-index weights of the reflectively measured modified IDI are similar to the weights proposed by the ITU, substantial weight deviations are detected for the formatively measured modified IDI. At the sub-index level, the access subscale had a considerably lower and the use subscale a considerably higher weight in the formative specification than in the reflective model. At the indicator level, much higher formative weights are assigned to "percentage of households with Internet access" and "percentage of individuals using the Internet". The two different measurement specifications are taken to calculate and compare modified overall IDI scores and resulting ranks for the sampled 137 countries. We conclude that weights of the individual indicators and the sub-indices in the IDI as suggested by the ITU may not be ideal if the target is to construct an index which is as closely as possible related to GDP per capita growth.

1. Introduction

The growing availability of efficient telecommunication networks and the increasing usage of information and communication technologies (ICT) services are major driving forces of a country's economic productivity and broader societal change and, hence, fundamental for the development of nations (Ishida, 2015; Kyriakidou et al., 2013; Shahiduzzaman and Alam, 2014; Vu, 2013). The measurement of this availability and usage at the country level is mostly conducted by aggregating distinct facets of a country's ICT capabilities (e.g., percentage of households with a computer) and service adoptions (e.g., percentage of individuals using the Internet) into a single composite index

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(ICT Development Index, IDI). From a practical perspective, such indices are intended to assess a nation's telecommunication sector in order to identify its strengths and weaknesses compared to other nations. The indices are typically taken by policy makers and ICT managers to justify public interventions as for instance, state subsidies to increase network coverage (Al-mutawkkil et al., 2009; Barzilai-Nahon, 2006). Furthermore, scholars from various disciplines investigate distinct methodological aspects of IDI measures.

Numerous IDI-based evaluations have been carried out by governmental or supranational organizations and scholars over the past years (see Section 2). The common first step in such analyses is to select a set of indicators which are subsequently transformed to the same unit of measurement, e.g. by using the distance to a reference value. In a second step, normalized indicators are weighted and merged into a composite index — either in a single step or by calculating sub-indices that in turn form a higher-level IDI (Munda and Nardo, 2005; Saisana and Tarantola, 2002).

A very prominent example for a composite ICT development index is the IDI published by the International Telecommunication Union (ITU) in 2009 (ITU, 2013b). It is updated annually and contains 11 indicators, which are merged into three sub-indices, namely (1) access (5 indicators), (2) use, and (3) skills (3 indicators each). Within the sub-indices, individual indicators have the same weight. The access and use subscales are weighted with a factor of 0.4 each and the skills composite has a weight of 0.2.

However, in addition to the question of whether the "right" indicators are selected, the ITU IDI and many other ICT indices exhibit two interlinked shortcomings: First, they compute an IDI as an end in itself because they fail to explicitly account for an IDI's power in predicting specific outcome criteria that translate into socio-economic achievements of countries. Consequently, many studies miss the opportunity to gain new insights on how socially and economically desirable conditions at the state level may be improved through targeted strengthening of ICT areas indicating room for development. Second, regardless of the hierarchical design of the IDI the relative importance of each indicator and sub-index (= weight), and thus a major driver of the results of the analysis, is either left to the discretion of the index builder or is based on inadequate measurement models in case that it is derived with the help of quantitative statistical data analysis. Hence, there is (still) room for improvement in constructing ICT development indices.

Consequently, the present paper addresses earlier construction problems through a modification of the ITU's IDI by linking its computation to gross domestic product (GDP) per capita change as a socio-economic target criterion. In order to maximize the explanatory power of the study variables with regard to this ultimate criterion, we refrain from setting subjective weights and instead model them as the linear combination, which is best suited to predict the outcome measure under study. In this context, the partial least squares (PLS) structural equation modeling (SEM) technique is a suitable statistical method because it estimates indicator and sub-index weights which maximize the explained variance of a target criterion (Chin, 1998; Hair et al., 2014; Henseler et al., 2014; Kyriakidou et al., 2013).

In contrast to previous IDI investigations using SEM, we additionally emphasize the choice of an appropriate measurement model which establishes the relationship between the latent constructs (i.e., sub-indices) and the observed indicators. From a general methodological perspective, two measurement options are available. A *formative* measurement model assumes that indicators capture distinct facets (e.g., fixed versus mobile subscriptions) of a construct. Thus, each individual indicator is a driver of the score of an (sub-)index. In turn, *reflective* specifications imply that the sub-index causes variations of its indicators which share a common cause and are exchangeable manifestations of the same underlying dimension (Chin, 1998; Weiber and Mühlhaus, 2014). The few investigations that applied SEM to advance the IDI of the ITU have implicitly opted for a reflective measurement model (e.g., Grigorovici et al., 2004; Kyriakidou et al., 2013). However, the ITU IDI claims to cover *distinct facets*. Thus, the specification of a formative measurement model may be more suitable. Nevertheless, no earlier work has estimated the extent to which indicator weights and resulting total country scores of an IDI vary depending on whether the index is specified reflectively or formatively. Consequently, the present study intends to contribute toward closing this research gap.

Against this background, the remainder of this article is organized as follows. Section 2 lays the foundation for our empirical analysis by reviewing the literature on existing IDIs with a focus on earlier studies' approaches concerning variable weighting and measurement model specification issues. Section 3 describes the data sources and the statistical methods applied in our modification of the original IDI. Section 4 first presents the results of PLS-based estimations of indicator and sub-index weights of the modified IDI (mIDI), comparing formative and reflective measurement models along with the resulting country rankings. Furthermore, regression findings regarding the contribution of each indicator in explaining differences in country ranks derived from the overall mIDI scores resulting from the two fundamentally different measurement models are reported. Implications and areas requiring further research are highlighted in the last section.

2. Literature review

An IDI is an aggregate of several indicators. It can be calculated in a single step if the included variables directly form the index or in multiple steps by incorporating at least one intermediate aggregation level of sub-indices. Regardless of its hierarchical design, the computation of an index requires the attribution of weights to indicators and – if applicable – sub-indices. Methods for addressing this weighting issue can first of all be classified into subjective judgments and objective operations research or multivariate statistical techniques. As a complementary, methods can be grouped depending on whether they derive weights which maximize the capability of an index to predict general or country-specific socio-economic target-criteria or not.

Several studies generate indicator/sub-index weightings from *expert opinions* (Barzilai-Nahon, 2006; Vicente and Gil-de-Bernabé, 2010; Waverman et al., 2011, pp. 41 and 63–64). The majority of earlier investigations (see Table 1) constructs *weighted summation scales* (cf. Hair et al., 2014, p. 140) by simply averaging or summing individual indicator values. This implies the assignment of equal weights to each indicator.

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