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A mega-index for the Americas and its underlying sustainable development correlations

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ABSTRACT

Indicators and their composite indices have been embraced as development tools for guiding humanity toward a sustainable destination. In response, public and private organizations have generated hundreds of these metrics, making their application overwhelming to policymakers, planners, and scientists. Past reviews have revealed that a majority of common development indices have theoretical or quantitative shortcomings, supporting that there is no consensus regarding their theoretical basis, design, use, thresholds-of-effect, or validation. In response, this study was designed around four guiding research questions: (*i*) What are the underlying development themes within a collection of established sustainability indices, and what distinguishes winning locations from losing ones? (*ii*) Are the three major divisions of sustainability (economic growth, social equity, environmental integrity) equally represented by current sustainable development measuring initiatives? (*iii*) Could just a few common and freely available indicators capture all present dimensions of sustainable development? (*iv*) Would a new sustainable development mega-index research paradigm improve humanity's ability to assess progress toward sustainability? Those questions were investigated using data from 30 mostly contiguous Western Hemisphere nations and three amassing methodological objectives. First, 31 known indices were reduced into underlying dimensions (factors) of sustainable development. Next, those factors were combined (aggregated) into the first mega-index of sustainable development (MISD). Finally, 11 common development indicators were explored regarding collinearity and explanatory power of the sustainable development dimensions and MISD. Seven latent dimensions (sub-metrics) captured over 85% of the variation of the original 31 indices, with socioeconomic themes dwarfing environmental ones. The factors conveyed: (F1) socioeconomic well-being synergies; (F2) economic freedom and democracy; (F3) environmentally efficient happiness; (F4) ecosystem well-being; (F5) peace to economic vulnerability tradeoff; (F6) natural resources protection; and (F7) environmental stewardship and risk resilience. MISD is the geometric mean of the seven sub-metrics, which were directed toward sustainability, and rescaled (normalized) 0 (worst case) to 100 (best case). Geographically, this study ranked Belize best overall, followed by Guyana, Panama, Uruguay, and Canada; Barbados ranked worst, preceded by Haiti, Trinidad and Tobago, Mexico, and Cuba. Winning countries were characterized by low population density, increased forestland, decreased urban, and larger country area. Child mortality and population growth rate remained negative predictors of socioeconomic conditions; however per-capita CO_2 sacrificed ecological integrity for improved human well-being. Mega-index creation will serve as an important scientific stepping-stone for improving accuracy and simplifying valuations of sustainable development, thus others should follow.

1. Introduction

We live in a time of unprecedented global change. *Environmentally*: Atmospheric greenhouse gasses continue to increase resulting in the warmest decade in Earth's recorded history (Seneviratne et al., 2014). Increased temperatures melt glaciers, ice sheets, and expand oceans, which exacerbate sea level rise and displace populations in coastal and island regions (Dutton et al., 2015). Further, the increased ocean temperatures have made global weather patterns less predictable and natural disasters more severe (Webster et al., 2005). Metabolization of natural landscapes has caused major ecosystem degradation and biodiversity loss throughout the world (MEA, 2005; Liu et al., 2007;

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Rockström et al., 2009; Shaker, 2015b; Turner and Gardner, 2015; Forman and Wu, 2016). Tropical rainforests continue to be exploited despite their known ecological services (Rands et al., 2010), ocean ecosystems are collapsing due to over harvesting (Worm et al., 2006), and eradication of our life-supporting ecosystems continues (Butchart et al., 2010). *Socially*: Inequalities remain regarding access to health care, freedom of expression, education, clean water, sanitation, technology, birth control, gender and religious equality (Griggs et al., 2013). Terrorism and fear have reached unmatched levels, resulting in significant reinvestments in military and defense, and accepting war as the status quo for solving social and political problems (Lum et al., 2006; Harcourt, 2008). Forced from their home nations, refugee populations are often neither welcomed nor treated equally in their new locations (Bauder, 2016). *Economically*: The world's richest countries continue to separate themselves from the poorest ones. Wealthy nations increasingly invest in their developing counterparts through progress loans, from sources such as the World Bank (Shaker and Sirodoev, 2016). In search of low-cost employment and lax environmental laws, globalization continues to move manufacturing from once-industrialized nations to developing nations (Krugman and Venables, 1995). *Governmentally*: Little legislative follow-through, corruption, decision-maker self-interests, and shortsighted policies keep trust in government and social capital low in many countries (Keele, 2007; Lyytimäki et al., 2013). These global problems are propelled and exacerbated by population growth and an increased demand for material well-being (Weinzettel et al., 2013), which have both been projected to have an indefinite future (Gerland et al., 2014).

"Sustainable development" remains the agreed upon and unifying approach to combat the negative impacts associated with global change. As defined by the Brundtland Commission's *Our Common Future*, sustainable development is: "development that meets the needs of the present without compromising that ability of future generations to meet their own needs" (WCED, 1987: 43). Although a uniting concept, it is impossible to know how to prioritize development strategies without assessing where we have been or our current position (Moran et al., 2008). During the 1992 Rio de Janeiro Earth Summit the need for indicators was solidified: "indicators of sustainable development need to be developed to provide solid bases for decision making at all levels and to contribute to a self-regulatory sustainability of integrated environment and development systems" (UN, 1992: 346). In response, by the end of the 20th century, hundreds of indicators had been created and structured into several comprehensive lists. For example, the *Compendium of Sustainable Development Indicator Initiates* was originally launched in 1995 and organized more than 500 such measurements (IISD, 2002; Parris and Kates, 2003b). During this sustainability assessment renaissance period, efforts were also made to focus initiatives into core sets of sustainable development metrics. In 2007, the United Nations report, *Indicators of Sustainable Development: Guidelines and Methodologies* provided a core set of 50 indicators drawn from a group of 96 (UN, 2007). At roughly the same time, the *Official List of Millennium Development Goals Indicators* established 60 indicators that addressed its needs (UNSD, 2008). Efforts continue to refine an indicator set for the European Union's Sustainable Development Strategy, which currently has more than 100 indicators across ten themes for its countries (Eurostat, 2015). There are 247 indicators across 12 topic areas currently inventoried for the Organization for Economic Co-operation and Development (OECD) member countries (OECD, 2017). More globally inclusive, a preliminary list of 231 indicators was endorsed to meet humanity's needs for 169 targets across the 17 Sustainable Development Goals (Sachs et al., 2016).

Public and private organizations have generated an overwhelming number of indicators and composite indices for assessing progress toward sustainability, making their application mind-boggling to policymakers, planners, and scientists (Rogers et al., 2008; Shaker, 2015a). Past reviews have revealed that a majority of common development indices have theoretical or quantitative shortcomings causing great misunderstanding for the sustainability effort (Böhringer and Jochem, 2007; Wilson et al., 2007; Mayer, 2008; Singh et al., 2012). Therefore, elucidating the strengths, weaknesses, scale-dependencies, data needs, construction, interrelationships, redundancy, and validation of these indices and the indicators on which they are based is essential for improving sustainable development monitoring programs (Parris and Kates, 2003a; Morse and Fraser, 2005; Ness et al., 2007). In an inductive study of 30 common sustainable development indices across Europe, Shaker (2015) found that socioeconomic measures overpowered ecological (biosphere) measures two-to-one. Recognizing that many sustainable development indices are environmentally weak, researchers have begun to supplement socioeconomic indices with indicators of environmental condition (i.e., Bravo, 2014); however, work remains to adequately capture and include biogeophysical complexities (Moldan et al., 2012).

Non-mathematicians have frequently driven the creation and use of indices (King et al., 2014; Phillips, 2015). This may accomplish the goal of making development metrics conceptually simple and understandable (see Maclaren, 1996), yet at the cost of calculation and accuracy errors. According to Böhringer and Jochem (2007), common sustainable development indices often fail to employ appropriate scientific requirements (i.e., geometric mean), or inaccurately conduct the three fundamental steps (normalization, weighting, aggregation), misinforming users (i.e., planners, policymakers) during their application. Therefore, no consensus has been reached regarding sustainable development index design, theoretical basis, use, thresholds-of-effect, or validation (Parris and Kates, 2003a; Keiner, 2006; Rogers et al., 2008). In response, policymakers have encouraged researchers to improve existing models and develop new techniques for optimizing local and regional sustainable development planning (Grosskuth, 2007). This sentiment was supported internationally at the 2012 Rio +20 Earth Summit, which focused on clear and practical measures for implementing sustainable development across spatial and temporal scales (UNCSD, 2012).

In response to the aforementioned issues with sustainable development indices, and current needs of sustainable development planning, this study was designed around four guiding research questions: (*i*) What are the underlying development themes within a collection of established sustainability indices, and what distinguishes winning locations from losing ones? (*ii*) Are the three major divisions of sustainability (economic growth, social equity, environmental integrity) equally represented by current sustainable development measuring initiatives? (*iii*) Could just a few common and freely available indicators capture all present dimensions of sustainable development? (*iv*) Would a new sustainable development mega-index research paradigm improve humanity's ability to assess progress toward sustainability? In the forthcoming paper, those questions were investigated using data from 30 mostly contiguous Western Hemisphere nations and three amassing methodological objectives. First, 31 known indices were reduced into underlying dimensions (factors) of sustainable development. Next, those factors (sub-metrics) were combined (aggregated) into the first mega-index of sustainable development (MISD). Finally, 11 common development indicators were explored regarding collinearity and explanatory power of the latent sustainable development dimensions and mega-index.

2. Data description

National-level development indices have reached such saturation that it is now imperative to critically evaluate their use for assessing progress toward sustainability. To maximize geographical variability, 30 nation-states across North, Central and South America, along with the Caribbean (hereafter: the Americas) were assessed in this study (Fig. 1). These countries capture a majority of the Western Hemisphere, are a microcosm of the global system, and represent an optimal study region for testing sustainable development hypotheses because: (*i*) the

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