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Reviewing Composite Vulnerability and Resilience Indexes: A Sustainable Approach and Application

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Summary. — Vulnerability–resilience indexes fail to grasp all dimensions of sustainability, whereas sustainable development has gained momentum. We fill this gap with a hierarchical multimetric composite index (Net Vulnerability Resilience Index: *NVRI*) whose robustness relies on a mathematical algorithm based on graph theory. A worldwide application shows that (i) both vulnerability and resilience are policy-responsive and that (ii) there is no determinism for a country to remain vulnerable or resilient. The *NVRI* enables us to identify a country's strengths and weaknesses and determine the policy orientations that should be implemented to achieve sustainability.

Key words — vulnerability, resilience, sustainable development, composite index, graph theory

1. INTRODUCTION

According to the literature, there is a general consensus that vulnerability impedes development (Atkins, Mazzi, & Easter, 2000; Briguglio, 1995; Briguglio, Cordina, Farrugia, & Vella, 2009; United Nations [UN], 2008). A country's vulnerability is usually defined by its degree of exposure to exogenous hazards – natural catastrophes and/or economic shocks (e.g., climate events, international trade instability, and market price volatility) – whereas resilience describes a country's ability to recover from a shock (Adrianto & Matsuda, 2004; Briguglio, 1995; Dabla-Norris & Bal Gündüz, 2014; Guillaumont, 2009, 2010; Guillaumont & Wagner, 2013; Rose & Krausmann, 2013). In recent decades, several composite indexes have emerged to quantify vulnerability and resilience (VR) on a macro scale (among others, Adrianto & Matsuda, 2004; Atkins *et al.*, 2000; Briguglio, 1995; Briguglio *et al.*, 2009; Guillaumont, 2009, 2010; Turvey, 2007; Wells, 1997). More specifically, these indexes particularly focus on growth descriptors to characterize a country's performance, whereas sustainable development has gained momentum. This conception of building composite indexes raises two issues:

(i) Though most of these indexes claim to stress the economic dimension of VR, they could be interpreted and/or expanded upon from a sustainable development perspective. Nevertheless, an in-depth analysis reveals that they do not simultaneously cover all of the dimensions of sustainability. Hence, an explicit interpretation of VR in terms of sustainability should be stressed.

(ii) The multiple variables and computation methods used to build composite VR indexes lead to the question of whether there is a minimum set of variables that consistently describes the studied phenomenon. As a result, reducing the number of variables to the greatest extent possible is a crucial issue and calls for finding efficient measurement procedures.

To address these two issues, a mathematical method suggests a hierarchical multimetric VR index (*NVRI*) from a sustainable development perspective (Bates, Angeon, & Ainouche, 2014). The soundness of this method relies on a mathematical algorithm based on graph theory that proves the paramount importance of jointly grasping the different dimensions of sustainability to build a holistic VR index. In this regard, this paper calls for renewing the art of computing composite VR indexes and advocates for reassessing the current state of countries' VR. The *NVRI* is then applied to a worldwide sample over the last decade to rank and compare countries' performance. Policy implications that complement international organizations' emphasis on sustainable development objectives are provided. They facilitate a high level of sustained and inclusive growth (World Bank, 2008) as a way for countries to mitigate, adapt to, and recover from shocks in a manner that reduces their vulnerability and consequently augments their resilience.

Thus, more evidence is given on the credibility and legitimacy of the *NVRI* in line with the positions of international organizations. The post-2015 Development Agenda includes sustainable development recommendations to boost progress toward the Millennium Development Goals in compliance with the Rio+20 Summit. The Development Agenda draws on key insights and policy levers that could help countries achieve sustainable and inclusive growth (World Bank, 2008). However, by omitting references to sustainability in VR indexes, no evaluation of the multifaceted characteristics of development is feasible. The worldwide spatiotemporal application demonstrates the value added by the hierarchical multimetric *NVRI* to identify a country's strengths and weaknesses and pinpoint the policy orientations that should be implemented to achieve sustainability.

The successive steps of the analysis are presented as follows: Section 2 uses key examples to survey the measurement of VR in development economics and provides evidence of some misconceptions that may have influenced the construction of currently used composite indexes. Section 3 reviews the mathematical basis of the *NVRI*. Section 4 describes the ranking of countries using a worldwide sample. Section 5 discusses

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the results by analyzing their practical policy implications, and Section 6 concludes.

2. THE ROOTS OF VULNERABILITY AND RESILIENCE

By surveying the literature on VR in development economics, numerous quantitative works that attempt to assess countries' performance can be found. We base our methodological investigation on an online survey using several academic search engines for references in economics. [1] The research is limited to papers that analyze VR from a macroeconomic perspective, with no limitations of date. By eliminating cross-references and articles with no direct links to macroeconomic development, 141 references are analyzed. This sample also includes the gray literature published by international organizations (10% of the total). These academic works reveal the predominant use of composite indexes to compare countries' performance. After defining what a composite index is, the most popular and/or most original articles found in the sizable body of literature are discussed. The strengths and weaknesses of composite VR indexes are then stressed.

(a) *Composite VR indexes: a methodological review*

This sub-section presents the rationale for composite VR indexes and their methodological underpinnings.

(i) *Defining composite VR indexes*

A composite index is an aggregation of a set of individual indicators that gives evidence for a multi-faceted problem using mathematical or computational methods. The justification for a composite index lies in its fitness for the phenomenon to be measured and its simplicity (European Commission, 2008). Before building or implementing a composite index, a theoretical framework must be followed to clearly define the meaningful basis for selection and the combination of variables used to compose the index (Montalbano, 2011).

The literature review shows that composite VR indexes encompass broad definitions of VR. Vulnerability arises from intrinsic permanent (or quasi-permanent) features and from external factors over which a country has no control. Thus, vulnerability results from structural features that increase the weaknesses of a system (herein, a macroeconomic system) during adverse shocks. These structural determinants are said to hamper development over the long run. Country size (population), remoteness (transportation costs), [2] and degree of economic specialization (e.g., the weight of the agricultural sector, export concentration) are some examples from the economics literature (Briguglio *et al.*, 2009; Guillaumont, 2009, 2010; UN, 2008).

Conversely, resilience refers to the capacity of a country to recover from a shock or to withstand a shock's impact (Briguglio *et al.*, 2009; Guillaumont, 2009; Montalbano, 2011; Rose & Krausmann, 2013). Resilience depends on domestically responsive internal factors and describes a country's ability to cope with its inherent vulnerability. Resilience therefore defines the capacity of an economy to minimize welfare losses and reinforces its development potential.

The seminal contributions on composite VR indexes stress their economic grounds, but they can also be interpreted from a sustainable development perspective that encompasses five dimensions: economic, environmental, social, governance and peripheral grounds (Bates *et al.*, 2014).

Composite VR indexes often serve to profile country performance. They determine, based on a given score, how close or far a country is from achieving resilience. Nevertheless, composite indexes reduce the multifaceted reality of VR to a single value. The resulting 'big picture' of composite indexes is easier to interpret than a battery of many separate indicators. It should be noted that the single value may ignore some key mechanisms at stake for a studied phenomenon. The same value of the composite index may hide different states of VR. Such a single value integrates the determinants of VR as if they were compensable.

To appreciate the extent to which a country may be vulnerable or resilient, understanding the integration process of the variables (weighting and aggregation) included in a composite index is of utmost importance.

(ii) *Aggregation and weighting issues*

Composite VR indexes are weighted or non-weighted averages of standardized variables. These indexes use aggregation processes that follow different principles and computation techniques. Not all indexes reviewed in the economics literature are presented here. 12 representative composite VR indexes have been selected. [3]

Two main methods are used to integrate the variables and sub-indexes into a single value.

First, regression models are estimated to calculate weights among variables. This method is followed by Atkins *et al.* (2000) to capture economic sources of vulnerability. The regression explains the dependent variable (GDP) using explanatory variables that refer to different sources of vulnerability. Adrianto and Matsuda (2004) also refer to a model to explain economic exposure as part of their composite index. Beyond complexity, one disadvantage of using a regression model is the integration of potential estimate errors from data that can be directly ready for use without additional estimates.

Second, an average of the various variables can be used directly. Adrianto and Matsuda (2004) compute weighted averages that associate their economic exposure sub-index with two other sub-indexes (economic vulnerability and the economic impact of natural disasters). Briguglio and Galea (2004) follow the same computation principle. Nevertheless, in previous works, Briguglio (1995) recognizes the subjectivity or arbitrary characteristics of an *ad hoc* weighting: "*alternative weighting schemes would not solve the problem of subjective choice*" (Briguglio, 1995, p. 1621). The author acknowledges that there is no evidence of the higher validity of weighted variables compared with non-weighted variables. Non-weighted variables would not change the message conveyed through a composite index in comparison with weighted variables. Moreover, because there is no absolute proof that such an econometric procedure can provide time-invariant weights, it would be difficult to determine whether fluctuations in the value of a composite index are due to an effective evolution of the VR state or to changes in the weighting system.

For the same reasons, assigning weights to indicators based on expert elicitation does not solve problem, either. Consequently, most of the composite VR indexes use a non-weighted average to integrate their components (the Composite Vulnerability Index of the Center for Environment and Development, 2002; Esty *et al.*, 2006; Kaly, Pratt, & Mitchell, 2005; Turvey, 2007; the Economic Vulnerability Index-*EVI* of the UN Committee for Development Policy, 2008).