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The world economy in a cube: A more rational structural representation of sustainability

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ABSTRACT

National economic systems are investigated in a 3-axis diagram where three different indicators are used to account for resource use, societal organization, and goods and services produced, respectively. This framework is consistent with an input-state-output (environment–society–economy) scheme based on a logical, physical and thermodynamic order between the three dimensions of sustainability. This approach highlights which input-state-output relations are realized and which relations are less common in the behavior of these systems. It assesses and overcomes major drawbacks of common representations of sustainability. Within a cube diagram, 99 national economies are ranked and grouped into 8 categories, which are labeled to reflect the main characteristics of their behavior according to the three environmental, social and economic parameters. A cluster analysis is also performed in order to statistically support the classification and strengthen the interpretation of results. Results show that no countries exhibit a dematerialization of economic activity and that non-sustainable economic activity can take place over a wide range of income distributions (Gini coefficients).

1. Introduction

Sustainable development can be viewed as a process of "interaction among three elements: the biological and resource system, the economic system, and the social system" (Barbier, 1987). A common representation of sustainability is that of three intersecting circles defined using these three dimensions (e.g. environmental, social, and economic). The intersection of the three circles is where sustainable development is realized. This representation supports the idea that sustainability must consider the goals of economic and social activity, together with environmental conservation. However this representation has two main weaknesses: (1) it does not include the temporal dimension of sustainability as intended by the Brundtland Commission "*Our Common Future*" Report (UN-WCED, 1987); (2) this framework, except in the very central area where all the sustainability requirements are satisfied, leads to consider the ecological, social and economic elements of sustainability as interchangeable or substitutable. The three circles representation consequently allows trade-offs between sustainability dimensions and allows reductions in the contribution of one dimension in order to improve the contribution of another. This substitutability between the environmental, social, and economic dimensions is often regarded as "weak" sustainability.

This classical viewpoint on sustainability inspired approaches based on a large number of juxtaposed indicators to monitor the development of countries, or systems in general (e.g. the Millennium Development Goals indicators – UN, 2000; the System of Integrated Environmental and Economic Accounting (SEEA) – UN, EC, IMF, and World Bank, 2003; the EU Strategy for Sustainable Development indicators – Eurostat, 2013, 2014). In a set of tens or hundreds of ecological, social and economic indicators, bad or low values of some can be compensated by very good or high values of others. Furthermore, the interactions between different indicators are not accounted for. For example, Costanza et al. (2014) highlight the interconnection "between built, social, human and natural

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capital required to produce human well-being", with a particular emphasis on the role of ecosystem services (MA, 2005). The supposed substitutability among these forms of capital is a problem that may create legitimate confusion which undermines the effectiveness of Sustainability Agendas (UN-SDSN, 2014) and Development Goals (French, 2005), as well as other tools for policy makers (Dessai et al., 2013; Glaser, 2012; Payne and Raiborn, 2001).

The use of a multidimensional representation is thus necessary, but the information embodied in a large number of different indicators has to be synthesized or represented in an easily readable form to be effective (e.g. in a sustainability index and/or in models). There is a tradeoff between the simplicity of single number indices and the detail in multi-variate metrics that attempt to characterize sustainability. Oversimplified indexes can hide serious issues associated with the fact that sustainability results from a suite of interacting variables. Nevertheless, keeping a large number of indicators completely separated often does not help the understanding of the overall sustainability/unsustainability of the system under study.

We suggest the adoption of a more logical/consequential approach for combining and evaluating different indicators in an environment–society–economy scheme, starting from the dependence of the economy on societal organization and environmental resources. An input-state-output framework will orient the use of a well-defined triad of systems indicators able to represent the interconnection of the three aspects of sustainability. In this way, the information gained by different indicators is not lost in final aggregations, instead it is maintained by keeping non-redundant indicators separated.

We claim that this approach can represent and monitor sustainability with a trade off that aims at maximizing information with the minimum numerosity of indicators: the information should be obtained by using indicators representative of the whole system; the numerosity is kept to the minimum to independently depict the three different dimensions of system sustainability, ensuring that every indicator maintains its identity, and complementary informative capacity. In addition, this approach allows for the relationships between different aspects of sustainability to be investigated by putting the environment, the society, and the economy in the proper relational order. We conducted a statistical analysis of a very rich nationally aggregated dataset which inspired a categorization of national economies worldwide. We believe this work will facilitate a basic representation of the nations of the world in a three-axis diagram that is proposed as a tool for static and dynamic investigations of sustainability, also usable for policy making.

2. The input-state-output (environment–society–economy) framework

A growing proportion of the scientific community recognizes that ecologic, social and economic elements of sustainability cannot be considered as interchangeable (Ostrom, 2009), and should be evaluated and represented in a holistic picture (Pulselli et al., 2008). This work strives for this holistic perspective that avoids the pitfalls of the 'Three Circles of Sustainability' approach. We have structured our representation of sustainability to consider the logical, physical, relational and thermodynamic order (i.e. environment–society–economy) that has been recognized by sustainability scholars (e.g. Costanza et al., 2014) and economists (e.g. Daly and Farley, 2003): "The linear flow of money and stuff is only a fragment of the larger real economy, embedded in human society. The economy and society are both embedded in the rest of nature. Without intact ecosystems and the services they provide us, neither can long survive" (Lovins et al., 2014).

Consider a three-storey pyramid to represent the mutual relationships among the three dimensions of sustainability (Fig. 1a). The base of the pyramid represents the natural assets, which form the crucial inputs to the system; the intermediate level

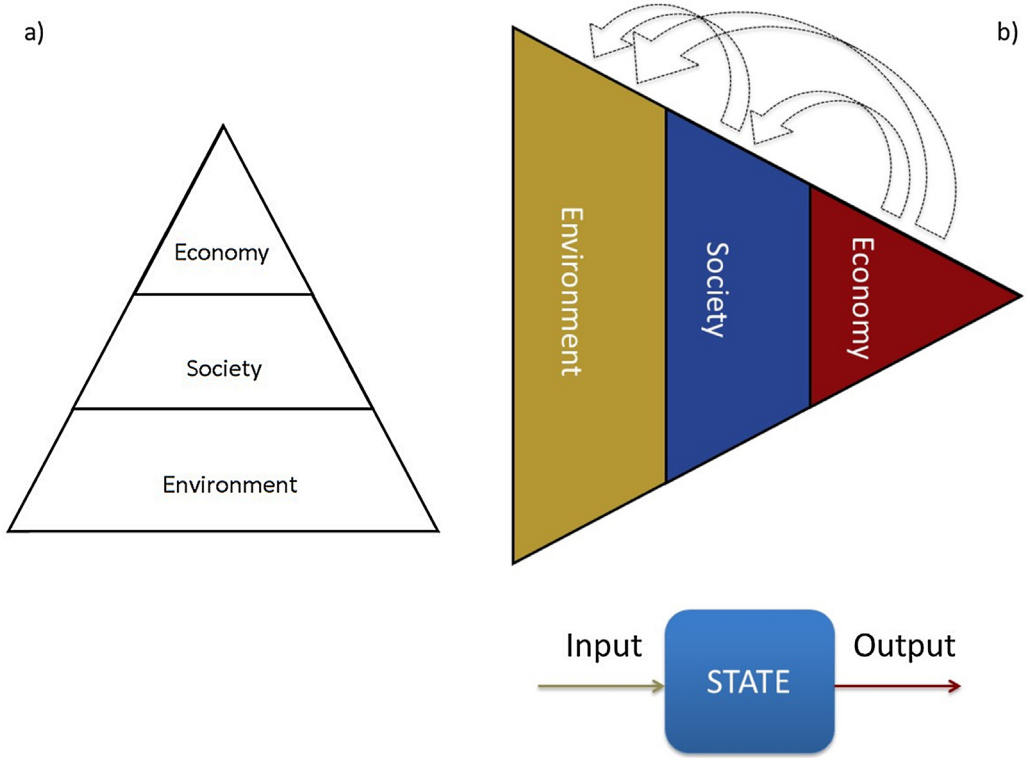

Fig. 1. A three-storey pyramid representation of sustainable development recognizes a relational and physical order of environment, society and economy. It resembles an input-state-output diagram to investigate economic systems. Feedbacks between compartments are also shown.