Categorization of National Economies through Environmental, Social and Economic Indicators.

Analisi e classificazione delle Economie Nazionali attraverso l'uso di Indicatori Ambientali, Sociali ed Economici.

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Abstract The definition of a sustainable economic model has to deal with environmental, social and economic aspects. National Economies can be described by a combination of measures in an input-state-output scheme. In this framework, a set of three indicators is used to identify different expressions of world economy. Emergy per capita is used as an environmental measure of input; employed to population ratio, as a social measure of the internal organization of the system; per capita GDP, as an economic measure of output. In this framework of analysis, different national economies can be compared, clusters are observed, and dynamics can be studied by taking into account natural, social and economic changes.

Abstract *Un modello di sviluppo economico sostenibile deve essere definito in termini ambientali, sociali ed economici. Le Economie Nazionali possono essere descritte da una combinazione di misure in uno schema input-stato-output. In questo schema, un set di tre indicatori è utilizzato per identificare diverse caratteristiche del sistema economico. L'Emergy pro capite rappresenta l'impatto ambientale dei consumi (input); il numero di occupati sulla popolazione totale è un indicatore sociale dell'organizzazione del sistema (stato); il PIL pro capite è una misura economica dei beni e dei servizi prodotti (output). In questo schema di analisi, le diverse economie nazionali possono essere comparate, raggruppate, ed analizzate in chiave dinamica considerando aspetti ambientali, sociali ed economici.*

Key words: Sustainability, input-state-output, national economies, emergy, holistic approach

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1 Introduction

Economies are open systems that self-maintain by exchanging energy with an external source-sink system (Fath, 2008). The functioning of any economic system includes the extraction of resources (energy and matter), the transformation of these resources through human labor, and the provision of transformed goods and services to the society (or to a portion of it). To investigate common properties shared by different economic systems, can be of help to represent it in a input-state-output scheme (Pulselli et al., 2011). This approach, already proposed for ecosystems categorization (Coscieme et al., 2013a), is very promising, helping to describe emergent properties, and, at the same time, the relationships between couples of indicators (input/output, input/state, state/output). In this paper is proposed an application to the analysis and categorization of national economies, using emergy per capita (Em_{pc}) as the input accounting method (Odum, 1996), employed to population ratio (TE/*pop*) as a descriptor of the organization level of the economy, and GDP per capita (GDP/*pop*) as a measure of the value of the services provided by the economy (Fig. 1).

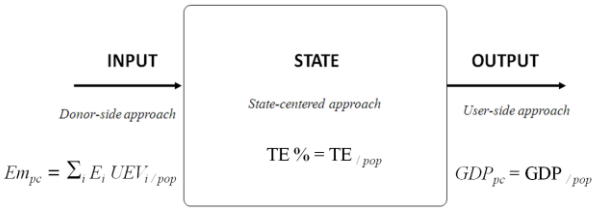

Figure 1: Input-state-output representation of a national economy by using emergy per capita for input accounting (Em_{pc}), employed over total population for state description (TE %) and GDP per capita (GDP_{pc}) for output accounting.

2 Methods

All the processes of transformation and production are based on resources (i.e. energy and matter). A particular mix of energy and matter inputs is somewhat specific for economies based on different transformation processes, in order to provide different services. Among the input accounting methods, the emergy synthesis is able to sum together the different energy forms, expressing it in a common unit, and can thus be able to represent properly the resource requirement of different economies. Emergy is defined as the quantity of solar energy (expressed in solar emergy joules: seJ) directly or indirectly necessary to generate a product or a flow (Odum, 1996). The total emergy of the inputs to a national economy can be represented by the convergence of different kinds of energy to the economy, times the quantity of equivalent solar energy that has been necessary to make available one unit (Odum, 2000; Odum et al., 2000; Bastianoni et al., 2011). Emergy has been calculated for different countries and data are available in the National Environmental Accounting Database: the NEAD (http://www.cep.ees.ufl.edu/nead/).

The NEAD considers the different types of inputs to an economy including renewable sources (sunlight, rain, geothermal heat, wind, and others), non-renewable sources (fossil fuels, metals, minerals, soil, water, and others), imported fuels, minerals, goods (including electricity), and services. The total emergy of the inputs can be considered as an indicator of the energy and matter that the national economy is using to self-maintain in its current status of organization, providing services to the society (Brown et al., 2009).

The Economies, as open systems, are naturally disordered, and cannot become organized and produce services without performing work (Ayres, 1998). In an Economy, all the transformation processes need to some extent human labour. The number of employed over the total population in a nation can be used as a descriptor of the organization of the economy. Data on employment at the national scale are available from the World Bank database (http://data.worldbank.org/; last accessed January 2014). The transformation processes convert resource input, into goods and services useful for the society. The market value of these goods and services, within a country in a given period of time (usually one year), can be considered as a measure of the outputs provided by the economic system (the GDP). This measure has been strongly criticized as a wrong measure of welfare or development (Leipert, 1986; Pulselli et al., 2008), but it is a well standardized and useful indicator for total economic productive output. In general, the indicators used for this categorization of national economies have been chosen for several reasons such as (i) they are consistent with the input-state-output scheme of investigation (Fig.1); (ii) they are available for a large dataset of countries; (iii) they are calculated by using standardized methods.

3 Categorization of National Economies

Through the analysis of world countries data (NEAD; The World Bank) it is possible to identify different configurations of input-state-output indicators. National Economies can be characterized by different relationships between the environmental, social and economic indicators.

Following the scheme proposed by Coscieme et al., (2013a) for ecosystems classification, we have investigated 100 countries for the year 2008, due to data availability. By dividing the range of values for each indicator in a low-dominion and a high-dominion interval, for values of the indicators respectively lower or higher than the median value, 8 possible categories of national economy can be defined. The number of countries classified in the proposed categories are listed in Table 1 and commented below.

Table 1: Categorization of National Economies through the input-state-output scheme (Fig.1). "low" indicates below-median values; "high" indicates above-median values.

Category	(I) Emergy per capita	(S) Employed/ pop	(O) GDP per capita	Number of countries
I	low	high	low	17
II	high	high	high	32
III	low	low	low	31
IV	high	low	low	6
V	high	low	high	13
VI	high	high	low	1
VII	low	high	high	0
VIII	low	low	high	0

I) The Economies classified in the category number I have a low emergy per capita, a high number of people employed, and a low GDP per capita. These Economies are characterized by a high number of people employed over the total population and consequently they have a high work capacity. A low amount of resources per capita, as measured by emergy, is used to produce a low market value of goods and services per capita. In this category are included some of the most populated world countries. The high population growth rate maintains a massive labor force. The very low level of GDP per capita, however, suggests that labor is underpaid and the economic system does not provide a broad and valuable set of services to the population.

II) The Economies classified in the category number II need a high amount of resources per capita in order to produce a high amount of goods and services per capita through the employment of a high fraction of the total population. The economic system in these countries provide employment and contribute to the welfare of people. However, the high amount of emergy required suggests an unsustainable behavior with respect to the global natural cycles. The adaptability of these economies to new environmental challenges that may lead to resource shortage is crucial for their welfare. The high number of employed and a sustainable provision of goods and services have to be maintained shifting from high dependency on non-renewables to a high reliance on renewables (Coscieme et al., 2013b). This shift will be measured by a decrease in emergy per capita that will be virtuous if high employment and services are maintained.

III) The Economies classified in the category number III have a low number of people employed and a low GDP per capita. These characteristics derive from a lack of resources, as highlighted by the low emergy per capita. This category is the most represented among the 100 countries investigated. A minimum level of per capita consumptions and raw materials for transformation processes are needed in order to maintain a minimum level of per capita GDP. It is interesting to note that some of these Economies are among the most populated countries (e.g. Mexico and India). Here a high level of total consumptions and a high total GDP are not equitably shared by the overall population. This inspires a debate about what scale of human presence and activity is sustainable by a national economic system, in economic, social and environmental terms. If we prove that the economic system fails in

providing services to a large population we should change our vision of development from one centered on “market-based” contribution to well-being to an alternative one centered, for example, on “land-based” or “environmental-based” contributions to well-being, in the light of the increasing global population that will take place in the next decades.

IV) The Economies classified in the category number IV are characterized by high consumption of resources, as measured by emergy, that is not used to maintain a large labor force nor to produce market goods and provide services to the population (i.e. they show low values of employed and per capita GDP). These Economies are ineffective in the transformation of inputs of energy and matter into economic services. The low value of GDP per capita does not derive from a quantitative lack of resources (they have a high level of consumptions per capita), but from a poor economy’s ability to generate employment and service flows.

V) The Economies classified in the category number V have a low number of employed to population and use a large amount of resources to maintain high GDP per capita. These economies pursue policies based on the idea that economic growth will increasingly contribute to the wellbeing of people. They are actually distracted by the old economic paradigm that strictly links welfare to the earning power. Today it is well-known that the concept of welfare or well-being is much more complex and overlaps with the concept of quality of life. It is also well-known that GDP does not actually distinguish between activities that produce welfare and those that increase defensive expenditures, nor does it consider the depreciation and devaluation of natural capital caused by unsustainable human activities (Pulselli et al., 2008).

In some cases the relationship between high emergy per capita, low employment and high GDP per capita occurs in countries that transform non-renewable resources of very high value, thus employing a modest labor force per unit value (e.g. Saudi Arabia).

VI) The Economies classified in the category number VI are characterized by a high number of people employed over the total population that use a high amount of resources per capita, as measured by emergy, and produce a low market value of goods and services per capita. The low GDP per capita suggests that labor is underpaid while the relationship between high emergy per capita and low GDP per capita indicates that the economy is highly inefficient in producing services and/or that the economy does not produce final goods and services but mostly intermediate goods and services that constitute exports and are not accounted as national GDP.

VII) An Economy cannot provide goods and services without using resources and employ people. This category is not represented by any country in our datasets, being all the production processes ultimately based on external resources. A broad understanding of this limit is fundamental for the formulation of a new development model and is the basis of the Ecological Economics that describes the human economy as a subsystem of the world ecosystem (Daly and Farley, 2003).

VIII) The economic systems cannot provide market goods and services without consuming resources and performing transformations through human work. None of the 100 countries analyzed falls in this category (low emergy use per capita; low employed to population ratio; high GDP per capita).

4 Conclusion

A common conceptual framework of the social, economic and environmental fields is needed to facilitate transdisciplinary efforts toward a better understanding of complex systems (Ostrom, 2009). In this paper, National Economies have been investigated and categorized in an input-state-output scheme: an environmental accounting method (Emergy) has been used for input quantification; a social indicator (employed over total population) has been used for state description; an economic measure (GDP) has been used for output accounting. This approach aims at creating a common framework to understand the relationships that occur among environmental resources, the society, and the economic infrastructures in a country. Nations are distributed in 6 of the 8 categories proposed. Some considerations emerge: (1) a dematerialized economy do not exists; (2) an high GDP per capita is subordinate to system organization, i.e. a high percentage of people employed; (3) categories II and III (Tab.1) are the most common configurations; (4) category V Economies follow developmental models that must not be taken as an example from developing countries. In particular their bypassing of societal wellbeing focusing only on increasing GDP may foster environmental, social and economic crisis in the next future.

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