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Review

A review of limitations of GDP and alternative indices to monitor human wellbeing and to manage eco-system functionality

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ABSTRACT

The misuse of Gross Domestic Product as a measure of public wellbeing results from the idea that economic growth is always synonymous with enhanced quality of life, disregarding the fact that the economy profits from natural, social, and human capital. In order to monitor progress towards sustainability and increased well-being, governments working closely with scientists developed new metrics that go further than income and material wealth. There are several candidates for revisions of the Gross Domestic Product. Based on a comprehensive literature review, this paper identified several possible indicators that intend to adjust, supplement or substitute for Gross Domestic Product. Two main approaches were identified. The first uses Gross Domestic Product as foundation to build a complete index and includes proposals to greening Gross Domestic Product, socializing the indices and including it in a more comprehensive index. The second approach relates to efforts to redefine the indicators, with the use of environmentally oriented indicators and socially oriented measures. Challenges to measure development, welfare, and wellbeing are discussed to provide a wide-angle view of efforts to develop measures of social-economic-ecological status and progress beyond the current very narrow Gross Domestic Product. It was recognized an urgent need for guidance for the development of governance regimes designed to change from short-term decision-making processes to those, which support the multi-decade planning and implementation processes that are needed to guide the transition to post fossil carbon societies. This comprehensive review covers a wide range of topics, from problems of GDP to challenges and thoughts about indicators. The review shows that if mankind is concerned with the sustainable development of the planet as a whole, then progress indicators measured only in monetary or social terms are limited and restricted to the weak or the medium sustainability model, and must be complemented by biophysical indicators. It is time to change the global knowledge of what progress really is, changing the discussion from growth to sustainable development and human well-being.

1. Introduction

Measures of progress can provide a fundamental connection between the economy and nations' policymaking establishment. The current default standard for economic and social progress is Gross Domestic Product (GDP), which is the most extensively established measure of a nation's economic performance (Marcuss and Kane, 2007; McCulla and Smith, 2007). Whereas its simplicity makes its use easy, there is an increasing acknowledgment that it is not adequate to fulfill the task of monitoring all of the relevant features for modern societies, governance, eco-system, exo-systems, policymakers and public. GDP assesses supply and demand through the account of the market value of goods and services produced and traded in a country during a given year. This index results from the simple addition of a country's individual consumption expenditures (households' payments for goods and services), governmental expenses (public expenses on the supply of goods and services, national debts, etc.), net exports (exports minus the value of imports), and net capital production (an increase in the nation's entire stock of capital goods). Reporting on the goods and services produced in the country either by domestic or foreign companies, the GDP is designed to answer how an economy grows, which fraction of production gains is due to inflationary trends, and how much of the gross income produced is used for consumption, investment or savings (McCulla and Smith, 2007).

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Since GDP limits coincide with the limits used to measure the population and employment of a country, this index is being used for establishing national policies and developing programs, and, unfortunately, to evaluate the quality of life in different countries. Governments regularly use changes in GDP as an indication of the success of economic and fiscal policies.

It is vital to understand that GDP is not intrinsically harmful or incorrect, but it measures only partial economic activities. Using it as an indicator of overall wellbeing is ambiguous and dangerous. "GDP is not wrong as such but is wrongly used" (Stiglitz et al., 2009). Stiglitz (2009) challenged the "GDP fetishism" and questioned whether current statistics produces accurate guides for policy or business decisions. Stiglitz also highlights that statistical frameworks intended to summarize what happens in a complex society in a few clearly interpretable numbers, such as GDP weak measures, may contribute to the degradation of living patterns. In the book "Mismeasuring Our Lives," Stiglitz et al. (2010) reviews the limits of GDP as a standard of the wellbeing of societies – taking into account, for example, how GDP ignores economic inequality and does not integrate environmental services into economic decisions. A list of the major problems of GDP as a proxy to sustainable societal development includes:

- It ignores several components that do not involve monetary transactions (Kubiszewski et al., 2013), excluding almost all non-monetary production, such as childcare or volunteerism, and the work done at home. Despite nonmarket production is partially integrated in GDP, such as government's defense, emergency housing and healthcare expenditures, many economic activities are excluded from its measures, such as donations, family unit's production of services, as well as many of the determinants of wellbeing such as the value of economic security, social relations and personal safety, health, and longevity (Anheier and Stares, 2002; Michaelson et al., 2009);
- It fails to assess changes in human capital (both social and organizational), and does not account for the circulation of income among individuals, which can enhance personal and social wellbeing (Wilkinson and Pickett, 2009);
- It counts every expenditure as positive and does not discriminate welfare-enhancing activity from welfare-reducing activity (Cobb et al., 1995). Defensive expenditures, for example, involve both crime-related costs, such as police, and security and noncrime related costs, such as insurance. These expenditures do not constitute a net increase in progress because they only prevent or repair social and environmental costs (Leipert, 1989);
- It ignores different visions of the goals of development, such as cultural differences (Henderson, 1996, 2010), overlooking the consequences of growing social-economic-political-ecological inequities. Because GDP does not address but often hides social and economic inequities, it does not properly provide societal insights into economic welfare due to escalating crime, reducing worker productivity and investment (Bernasek, 2006). When the growth is concentrated in only one portion of the society, it does not contribute to improving global economic prosperity because the social benefits of increases in consumption by the rich are less positive than increases in spending by the whole community (Talberth et al., 2007);
- It omits the environment, ignoring environmental costs, natural resource depletion rates, and, contradictorily; it includes the costs of environmental remediation as valuable production. Moreover, it disregards longer-term negative consequences of short-term exploitation of the ecosystem and of eco-system's services, which reduce the system's capacity to function in a million ways.

The list makes clear that GDP not only falls short in evaluating critical aspects of quality of life, but it also triggers and fosters activities that are contrary to long-term societal well-being. Although there is value in using GDP as one economic indicator, it is clear that it does not provide a full and reliable appraisal of a country's economic health for the present or the future and certainly does not address quality of life, happiness, wellness and other crucial societal parameters. More important, GDP and most national accounting systems are limited by national borders and mostly ignore unsustainability generated by isolated actions in each country and the effects of national development on the overall biosphere or individual countries. GDP and wellbeing may grow in a country by exporting the negative aspects of its growth to other countries, at the expense of ecosystems and the wellbeing of the workers in developing countries (Helm et al., 2007), with implications for policy towards developing countries that supply the developed economies with raw materials, manufactured goods and services, some of which previously produced by the same developed countries.

A distinct concern about GDP as a measure of progress is the idea that, as GDP increases, overall quality of life will also increase. Beyond a given point, increments in GDP are counterbalanced by the losses related with increasing income inequality, lack of leisure activities, and natural resource consumption (Talberth et al., 2007). Additional increases in economic wellbeing may lead to adverse results such as the lessening of the people's healthy relationships, knowledge, contact with nature, and many other dimensions of individual wellbeing (McKibben, 2007). According to Max-Neef (1995), although traditional economics equates the desire for material products to the satisfaction of needs, it can also be achieved via material and nonmaterial issues such as access to education, cultural events and healthy community relationships. Claiming that GDP is acknowledged to be a poor measure of social well-being, England (1998) critically survey a number of quantitative measures, which have been proposed as complements or substitutes for GDP. England classifies the alternatives as combinations of the need to (i) understand the difference between intermediate and gross final outputs, (ii) account for asset depreciation in a broader manner; (iii) separate net final output between consumption and capital accumulation; and (iv) take account of the welfare implications of various forms of social inequality. GDP misuse also accelerates the use of natural resources damaging ecosystems and decreasing the ecosystems' services (Costanza et al., 1998). These services only provided by a healthy ecosystem include biodiversity maintenance, sequestration of carbon dioxide, air cleansing and water quantity and quality management, flood reduction or prevention, are not accounted by the market economy and GDP.

Criticisms are not new, and it is clear that the current GDP must be replaced, or at least its role needs to be reviewed. Otherwise, the entire societal system will collapse, under short-term greed and other myopic views that block the development and utilization of appropriate decision-support tools that can help societies, industries, and universities to develop and implement multi-decade and multi-generational planning processes.

With the objective to address these concerns about the limitations of GDP and the need for tools, which that can effectively guide and monitor the transition to truly sustainable, post–fossil carbon societies, this comprehensive literature review evaluates the content, scope, potential applicability and benefits of using alternatives and supplements to GDP; and to revive the debate bringing up some issues that are still little discussed:

- What indicators should be used to evaluate progress towards SD?
- Who will select those indicators?

- To whom those indicators are of interest?
- How would they be measured?
- What can be done within the possibility of the existing accounts?

The structure of this paper is in the following: in Section 2 alternatives and supplements to GDP are described, and we discuss the efforts to establish a new indicator in Section 3. The major progress/sustainability indicators were reviewed and discussed, among them: Green Gross Domestic Products, Genuine Savings (GS), Genuine progress indicator (GPI), Physical quality of life Index (PQLI), Human development index (HDI), Emergy, Exergy, Gross national happiness (GNH), Happy Planet Index, Wellbeing Index (WI), Country Futures Indicators and Calvert–Henderson Quality of Life indicators, Sustainability Index, Index of Sustainable Economic Welfare. In Section 4, the difficulties to measure progress, welfare and wellbeing are examined. In Section 5, a summary of the fundamental conceptual requirements to build a progress indicator differentiating its ability to measure weak, medium and strong sustainability is presented, and finally, we provide concluding remarks.

2. Proposed alternatives and supplements to GDP

As a way to fulfill the shortcomings of GDP while acknowledging its virtues, an increasing number of individuals and teams have developed alternatives and supplements to GDP to explore more comprehensive measures of societal wellbeing and eco-system health. Two main approaches are identified. The first uses GDP as foundation to build a complete index and includes proposals to greening GDP, socializing and including GDP in more comprehensive indexes, such as the Sustainable Wellbeing Indicators and the Human Development Index (HDI). In the second approach, indices are constructed independently of GDP, with the idea that progress does not depend on economic growth, but on personal wellbeing and environmental limits. Efforts to redefine progress measurements include environmentally and socially oriented indicators.

2.1. Greening GDP

To direct GDP's shortcomings to indicate the condition of society and its segments, several possible indices and sets of indicators have been proposed as supplements to GDP. In general, most of the proposed indices seek to rectify, correct or add elements to be integrated into the array of inputs to be used in calculating GDP. Some proposals use the national accounts and GDP as a foundation and then subsequently add or subtract quantities in an effort to address part of the issues raised by many researchers (Costanza et al., 2009; Stiglitz et al., 2010).

The attempts for greening GDP include estimates for depletion of natural resources and environmental degradation into the nations' income accounts to achieve a single number. Repetto et al. (1989) proposes a depreciation adjustment to account for different forms of natural resource depletion. Using the Market Value Approach, assets are valued by applying the existing prices observed in the market by the extent of assets/goods produced or placed in stock. Repetto et al. (1989) emphasizes that, especially for nations heavily dependent on natural resource production and exports, the omission of resource exhaustion from their accounts results in overstated numbers for both net production and capital accumulation and do not address the depletion of the stocks or the potential for regeneration of ecological resources. Questioning the use of annual changes in the market value of reserves of natural resources, El Serafy (1993, 1996) introduces the “user cost” of natural resource consumption as an amendment to GDP. The user cost method defines true income as the amount that would be sustained for the foreseeable future despite the actual finite lifetime of the asset by suitably reinvesting a portion of the profits generated to ensure the future income. Developers of the user cost methodology emphasize that nations that rely on the natural resources exploitation to increase their GDP growth rates usually use incorrect values to make decisions and implement public policies. However, the use of this method met no consensus about how to correctly account for income and how to reflect changes in the environmental stocks. Some limitations of this method include several assumptions such as holding constants the profit rates, the rate of extraction until the final exhaustion of the resource; and the discount rates.

Other supplemental accounts intend to determine progress and wellbeing by incorporating sustainable resource utilization measurements into national income accounting, rather than estimating monetary values for environmental issues and including them directly in the GDP. Sustainable National Income, developed in the Netherlands, compares national income estimated to be sustainable for that of conventional national income accounting practices, without directly incorporating social factors in its calculations (Hueting et al., 1993). The gap between the two records describes the country dependence on natural resource use that exceeds sustainable utilization (Gerlagh et al., 2002).

In 1993, a system originated by the input–output method (Leontief, 1970) was organized based on the works of Keuning (1992, 1993) and de Boo et al. (1991, 1993). The National Accounting Matrix including Environmental Accounts (NAMEA) blends standard economic accounts with a system of environmental and economic accounts in a matrix, producing a frame for reviewing and outlining economic and environmental policies. Contrasting to Green GDP, the NAMEA's indicators are recorded in physical units avoiding to value the intangible costs and to subtract them from GDP. Another statistical framework is the System of Environmental-Economic Accounting (SEEA), a collection of statistics and indicators for policymaking, investigation and research (United Nations, 2014). The SEEA 2012 was published under the sponsorship of the United Nations, the European Commission, the Organisation for Economic Co-operation and Development, the World Bank, the International Monetary Fund and Group the Food and Agriculture Organization of the United Nations. Degradation and other issues associated with ecosystems are not granted, but there is a definite description of the physical flows to be considered by the System of National Accounting: cultivated biological resources and flows to controlled landfill sites.

Talberth and Bohara (2006) developed models of green GDP growth analyzing the gap between traditional and green GDP, and examining eight countries across 30–50 years using the openness index. This index is an economic metric calculated as the ratio of each country's total trade (imports plus exports) to the country's GDP. The higher the index, the larger will be the effect of trade on domestic activities. The effects of economic openness show negative nonlinear relationships with green GDP growth and a positive nonlinear correlation with the gap growth between traditional and green GDP. Talberth and Bohara (2006) conclude that a green GDP time series could be useful for re-examining parameters that may affect the rate of growth in economic welfare.

With the objective to gather and provide information to overcome the limitations of GDP, leaders of 189 nations signed the United Nations Millennium Declaration, in 2000, laying the basis for eight international goals for underpinning improvement in the overall human condition. The goals consist of developing a global community for progress, eradicating extreme hunger and poverty, achieving widespread primary education, promoting gender equity and empowering women, diminishing child mortality, improving

maternal health, combating illnesses, and assuring environmental sustainability. Forty-eight indicators are offered to measure progress towards societal achievement of these goals (UN DESA, 2007). The *Handbook of National Accounting: Integrated Environmental and Economic Accounting* published a list of four categories of accounts, to be complementary to the System of National Accounts (United Nations, 2003). The Handbook includes information about the use of energy/materials and the generation of solid waste and pollutants at the industry level; the money spent by government, industry, and households to protect the environment or to sustainably manage natural resources; the stocks of natural resources (land, fish, forest, water, and minerals); and how nonmarket items are valued and adjusted for degradation and natural resource depletion. The Handbook does not include social capital components, although other efforts to produce complementary accounts are designed to monitor components such as health, education, volunteer activity, and household production. This approach in producing complementary accounts is a way to provide further information, but avoids the difficulty or responsibility of integrating such information into the existing System of National Accounts.

The Genuine Savings (GS) shows the level of savings in a country after depreciation of produced capital (World Bank, 1997). Within GS, investments in human capital (education); depletion of minerals, energy and forests; and damages to the environment are measured by the market price of global damages from carbon emissions. Intangible wealth is associated to the social and human capital and includes abilities and expertise of the labor force, legal systems, property rights, and administration. GS subtracts environmental degradation and resource reduction and adds investments in human capital to the GDP. GS was calculated for 120 countries, and results suggest that the main form of wealth is intangible capital, human capital and the quality of formal and informal organizations. The distribution of produced assets in total prosperity is practically constant among income groups while the share of natural capital tends to decrease with income at the same time as the share of intangible capital increases. These observations are used to explain why rich countries are rich, considering their populations' capabilities and the quality of the institutions underneath economic activity. However, Uwasu and Yabar (2011) analyzing countries' sustainability conditions using GS report that the nature of institutional and population growth, along with natural resource abundance, significantly influences capital accumulation in the long term but that a good performance of GS does not guarantee SD. McLaughlin et al. (2012) reports similar results using a time series (1760–2000) for produced, natural and human capital in United Kingdom to derive GS. Using the coal extraction to represent the depletion of Britain's natural resources, they state that less than 20% of Britain's coal has been extracted since 1760. McLaughlin et al. (2012) question why coal extraction equates to a diminishing of wealth if most British coal will not be exploited on a plausible timeframe. These authors claim that the connection between the extraction of natural resource and progress within the GS framework must be reevaluated through defined timeframes.

Unfortunately, there are still no global data to support the validity of these alternative approaches. Most of the studies deal with partial results showing local or country-specific initiatives (Sébastien and Bauler, 2013; Heberling et al., 2012), methodological challenges to ecosystem accounting (Edens and Hein, 2013), and potential economic results (Bhattacharyya and Hodler, 2014) without a longitudinal application of these methods for long periods. Although a useful policy suggestion that come out from Green GDPs is that countries that depend on natural resources need to include them into the formation of other forms of capital, the value and the use of Green GDPs in policy-making still depend on accurate measures of the natural capital losses and their relationship with progress and well-being.

2.2. Socializing GDP

A foremost problem of GDP is that it does not take account of the welfare implications of various forms of social inequality. The economist Amartya Sen (Sen, 1981, 1992) addressed the problem of social inequality and its implications for social welfare, and his vision was explored to create the Human Development Index (HDI). The intent was to verify how the provision of economic growth and human development is or is not improving individual prosperity in national scenarios. The index accounts for "longevity, knowledge and decent living standards" as representatives for people's capacity to live long and prosperous lives. Life expectancy at birth represents other features of wellbeing such as good nutrition and health. Knowledge is included using literacy rate and school time, as a proxy of the adult population level of education, and access to a proper standard of living is related with GDP adjusted to reflect buying power parity using a logarithm of real GDP per capita. Despite the HDI being considered as a step forward in relation to GDP alone, it has been heavily criticized for not considering the environmental costs of development (Hsu et al., 2013; Carmignani, 2013). The authors also recognized the difficulty of quantifying the resources needed for a proper standard of living, civil liberty, guaranteed human rights and personal dignity (UN Development Program, 1990). A series of related issues is also listed, such as the relationship between consumption and well-being, employment and wages, the impact on employment by technological advances; and inequality, which are not represented by the HDI (Vergragt, 2012).

Some limitations of the HDI are highlighted to explain the alleged side effects of progress (such as unemployment, crime, health needs, environmental pollution, family disruption, etc.). The Human Poverty Index (HPI, 2010), for example, derives from HDI and has been reported since 1997 by the UNDP. HPI measures the loss in basic human development in terms of the percentage of people to whom life expectancy does not reach 40, the percentage of uneducated adults and the creation of economic conditions for an acceptable standard of living in terms the percentage of people without access to health services and safe water and the fraction of children under five years who are underweight. The HPI was built for the application to developing countries (HPI-1), and industrialized countries (HPI-2) because human deprivation changes with the social and economic circumstances of the community.

2.3. Greening and socializing: the Sustainable Wellbeing Indicators

One of the first measures of economic welfare was MEW (Measure of Economic Welfare) developed by Nordhaus and Tobin (1972). As an alternate for GDP, this index measures consumption as a proxy for economic welfare. The MEW is designed to measure economic welfare by adding up the benefits, such as the consumption of goods and services while subtracting costs such as pollution. Among several modifications, investments in human capital for education and healthcare are excluded from the calculation, as well as expenditures for national defense, police and sanitation. The results of MEW, according to Nordhaus and Tobin, are so similar to that of GDP that an independent economic welfare measure is deemed to be superfluous. Nordhaus and Tobin also provide an evaluation called SMEW (sustainable measure of economic welfare) including the level of MEW that is well-matched with preserving the natural capital. SMEW values the US over the 1929–1965 period were compared to GDP, and the conclusion was that GDP growth remained a satisfactory guide for policy (Afsa

et al., 2008). However, a number of other measures of economic welfare were developed after MEW, such as the Index of the Economic Aspects of Welfare (EAW), which includes environmental costs (Zolotas, 1981).

Inspired by these two attempts, MEW and EAW, Daly et al., 1989 developed the ISEW (Index of Sustainable Economic Welfare), an index that accounts for current environmental issues and long-term sustainable use of natural ecosystems and resources (Valentin and Spangenberg, 2000; Pulselli et al., 2008). The ISEW uses GDP as a foundation and measures the portion of economic activity that provides direct improvements in the quality of life by considering that welfare is affected by the flow of services to mankind, rather than by the current production of marketable goods and services (England, 1998).

The ISEW was reviewed and renamed the Genuine Progress Indicator (GPI), in 1995, as a proposal to replace GDP by 'Redefining Progress,' a nonprofit organization. The GPI measures the progress of nations by considering human welfare and the environment (Talberth et al., 2007). The indicator uses the same methodology for calculating GDP, but deducts the costs arising from items such as crime, pollution, environmental degradation and depletion of resources, while it adds items as volunteer work. By untying activities that diminish welfare from those that enhance it, the GPI intends to reveal the sustainable prosperity (Posner and Costanza, 2011). Analyses conducted in the U.S. show that, from 1970, the GPI decreases while the GDP increases. A study published by Kubiszewski et al. (2013) presents estimates of GPI/capita over 1950–2003 for 17 nations showing that global GPI/capita peaked in 1978, at the same time that the global Ecological Footprint exceeded global biocapacity.

The ISEW and GPI were criticized extensively for lacking a solid theoretical foundation (Harris, 2007; Brennan, 2013). The main criticism was that ISEW and GPI were unable to reflect both economic welfare and sustainability. GPI is a measure of economic welfare that needs to be supplemented by biophysical indicators to determine whether the economic welfare being enjoyed is sustainable (Costanza and Patten, 1995; Lawn, 2013). Applications of these new accounting systems provide undeniable indication of a growing gap between GDP and economic wellbeing (Pulselli et al., 2008, 2012, Beça and Santos, 2010), indicating that, along time, economic activity may be self-canceling from a welfare perspective (Max-Neef, 1995).

All these alternatives or supplements to GDP still have limitations, which include:

- the subjectivity in deciding which expenses are valuable and must be added to the total and which are disruptive, and must be subtracted;
- the need for consensus on how to value social and environmental items that are not reported in monetary terms (ecosystems services, natural resources, volunteer labor or illegal activities);
- the need for consensus on how to quantify the costs of natural resources depletion;
- the subjectivity of selecting and classifying the most representative variables and/or indicators that form the basis of the indices.

Besides, there are different ways to assign monetary values to environmental and social items, such as the Contingent Valuation method (Whitehead and Haab, 2013) that uses surveys to guesstimate people's willingness-to-pay for specific nature's goods and services, or the Hedonic Pricing method that focuses primarily on property markets through analyzing prices influenced by its surrounding properties (Sander and Haight, 2012). There are also other techniques for monetary valuation such as Factor Income, Avoided Cost and Replacement Cost that can be used (Pearce et al., 1994).

All of these measures, like GDP, show a macroscopic view and still show weaknesses, but they can and are being used to assist local and regional decision-making (Pulselli et al., 2008, 2012). Nevertheless, these measures represent an improvement on the misuse of GDP and economic growth as a representative for well-being.

3. Efforts to redefine the indicators

The differences between measurements of GDP growth and green GDPs challenge the notion that increased production equals progress. The recognition of a new viewpoint provides an opportunity for the construction of an alternative framework for measuring progress, which employs different approaches from that used in measuring GDP.

The experiences in changing or complementing GDP as an indicator of progress show that high consumption of natural resources does not automatically create wellbeing (Repetto et al., 1989; El Serafy, 1993, 1996), and that it would be possible to produce wellbeing without excessive consumption. Efforts to create a progress indicator consistent to SD can be divided into three categories: those that are mostly committed to assessing the environmental drivers to welfare, those driven by human needs and those, which are designed to incorporate both approaches.

3.1. Environmentally oriented indicators

Most of the environmentally oriented indicators were designed to monitor progress toward SD, instead of measuring societal progress, and three promising techniques that show potential for sustainability assessment at various scales are exergy, emergy, and the ecological footprint. According to Bastianoni et al. (2005), the use of environmental oriented indicators for SD assessment is defensible as a result of Herman Daly's first principle of sustainability (Daly, 1990), in which renewable resources should not be used more rapidly than they can be regenerated. These principles imply that some appropriate metrics for material and energy balances should be adopted to go beyond the narrow limits of the GDP.

At this point, it is imperative to make a distinction between weak and strong sustainability. The indicators described in Section 2 even framing the problem in terms of human wellbeing, are based on the economic approach and account only for the natural environment functions/resources providing for humans and the economic system. Those indicators account for the optimal income to achieve progress/well-being, and aim to provide information on how much to consume at the present and how much to spend in the future in built capital. However, there is no clue if this optimal income, is sustainable in the sense of allowing welfare for future generations. On the one hand, the concept of weak sustainability does not take account the thresholds in natural resources or limits to the substitutability among natural and produced capital. On the other hand, the environmentally oriented indicators are built upon biophysical variables that should determine the possible ecological limits to growth (Nourry, 2008). Under the concept of strong sustainability, natural capital cannot be substituted by human and social capitals.

Some indicators assess the energy availability for the societal wellbeing. Energy analysis focuses on all of the energy flows in the economy, which are commonly associated with measurement of progress, such as the night-time satellite imagery sustainability (Sutton, 2003). This measure is done by dividing the amount of light energy emitted by a nation (measured by a night-time satellite image) by the total nation's ecosystem capital (measured by a land-

cover dataset). The analysis provides an overview of the effectiveness of resource utilization and shows where losses take place and technological improvements can be made to increase energy efficiency and distribution.

Energy analysis can also be done using special energy measures, such as exergy and emergy. These metrics provide material and energy balances, and can be adopted as part of a wide-ranging sustainability assessment. Both exergy and emergy analysis consider the quality and the amount of energy (Rosen and Dincer, 2001; Herendeen, 2004).

Odum (1996) created an assessment system for emergy synthesis where all resources and goods are expressed in terms of the energy needed for producing them. He introduces emergy as a measure of real wealth to account for evaluation of environmental and economic use. The emergy is the embodied energy required to produce goods and services, and it is useful for assessing energy scarcity, availability, and energy efficiency in the management of natural resources (Hoang and Rao, 2010; Warr et al., 2008). A key improvement of the emergy theory is that it accounts for availability of the free ecological resources (sunlight, rain, wind, tides, etc.) and differentiates renewable resources (agricultural production hydroelectricity, etc.), non-renewable (fossil fuels, metals, minerals and soils) and imported resources (services, fuels and materials), with results reinforcing emergy accounting as a self-consistent method with high robustness (Giannetti et al., 2013a, b). A debatable aspect of emergy synthesis is its approach towards connecting environmental resources and their economic use. Odum (1996) claims that real wealth derives from environmental resources while the income required for progress depends on how much real wealth (measured in emergy) is available. By dividing the emergy use by the GDP of an economy, it would be possible to define the real buying power of money in a given country, and consequently, the optimal income to support progress and well-being. A National Environmental Accounting Database (NEAD, 2014; Sweeney et al., 2007) is available providing detailed information, from 2000, 2004 and 2008. For over 150 countries, the full assortment of resources that lie beneath economies includes environmental flows, natural capital stocks, metals, fuels and economically transformed goods and services. Several publications demonstrate the use of emergy to evaluate national sustainability representing various aspects of nations' conditions (Brown and Ulgiati, 2011; Lou and Ulgiati, 2013), and analyzing the paths to SD (Giannetti et al., 2010, 2013; Hossaini and Hewage, 2013) using the methodology as an alternative to measuring real progress beyond GDP.

Exergy or available energy is a thermodynamic property of a system that can be defined as the maximum work that can be extracted from the system (Balocco et al., 2004) and can be perceived as a measure of its quality or potential to change. According to Dincer (2002), exergy accounting can provide policy guidance on SD since it addresses the impact on the environment of energy utilization and quantifies energy losses and waste providing information for efficient resource use. There are examples of exergy analyses for China (Shao et al., 2013), Canada (Bligh and Ismet, 2012), and the United States (Ayres et al., 2003).

Three methods derive from exergy intending to amplify calculations in order to measure progress and sustainability: Extended Exergy Analysis (EEA), Ecological Cumulative Exergy Consumption (ECEC) and eco-exergy. EEA correlates exergy and economic value by providing a theory of value similar to that of emergy synthesis, addressing and quantifying capital flows and labor in thermodynamic terms (Milia and Sciubba, 2006; Sciubba, 2001, 2003a, b). The ECEC accounts for the free ecological processes using emergy derived procedures (Ukidwe and Bakshi, 2007), but this approach was only applied to US (Ukidwe and Bakshi, 2004). Finally, the eco-exergy defines the ecosystem's health as the distance from thermodynamic equilibrium (Bendoricchio and Jorgensen, 1997; Verdesca et al., 2006). As an indicator of sustainability and ecosystem health (Jorgensen, 2006a, b; 2007; Jorgensen and Nielsen, 2007), eco-exergy has recently been used in larger human systems such as countries (Jorgensen, 2006a). However, despite the strong and universally accepted methodological foundations of exergy, its use in larger systems is still under development, and there are no global data to support the exergy validity to measure progress towards sustainability.

The most known biophysical method to evaluate progress towards sustainability is the Ecological Footprint (EF), possibly due to its simple visual tool that quickly communicates to the non-experts. The EF was developed to account for flows of matter and energy into and out of the human economy and to convert those flows into a measure of the area of fertile land and water supporting those flows (Wackernagel and Rees, 1996). This methodology assumes that it is possible to follow the course of all the materials and human services required supporting a population and that most of these inputs can be converted to a corresponding biologically productive area. Since 2002, the EF has been used to calculate the hectares used to sustain human's consumption and waste generation.

These biophysical approaches intend to explain the relationships within complex human systems through natural science perspective. Nevertheless, they share the idea of strong sustainability without being direct measures of it. Furthermore, all three methods use a common concept of value that is entirely different from that of GDP. Emergy is accounted based on how much energy, effort, materials, time, etc. are invested to produce real wealth (Odum, 1996), Exergy estimates how much work is embedded in a commodity in the form of materials, labor or capital (Sciubba, 2003a), and the EF is obtained according to how much bioproductive land must be taken by a given population in order to achieve welfare. Their core fundaments contrast to those of traditional economic analysis as they consider the environmental limits to develop and growth.

3.2. Socially oriented measures

The physical quality of life index (PQLI) is considered the first composite measure of progress that is not built upon utilizing income or economic wellbeing. The PQLI employs an index ranging from 0 to 100 based on equal weights, which measures infant mortality, life expectancy and basic literacy (Morris, 1996). The PQLI is based on the assumptions that there are several patterns of development, which the indicator must measure results and not inputs and that it should be able to reflect the distribution of social needs. More importantly, it is easy to construct and easy to understand (Morris, 1979). The index shows that some countries have much poorer life-quality results at relatively high per capita incomes, suggesting that the growth of disposable personal income over time not necessarily improve progress.

Another non-monetary approach to measuring progress is the Gross National Happiness (GNH). This concept, which is often mentioned as an alternative measure of progress, was developed in an attempt to establish an indicator that measures quality of life or social development in more holistic and psychological terms than GDP. GNH was originally suggested by the King of Bhutan in the early 1980s in commitment to building an economy that would serve Bhutanese specific culture. The developed GNH is a conceptual, philosophical and political framework designed to measure the population's general level of well-being. It is being used to guide Bhutanese political decisions based upon Buddhist spiritual values rather than on increasing economic activity (Ura and Galay,

2004). The four pillars of GNH are establishment of proper governance, the promotion of SD, the conservation of the natural environment and the preservation and promotion of cultural values.

Progress on achieving the goals within these four pillars is investigated through specific indicators/contributors to happiness: time use, living standards, good governance, psychological well-being, community vitality, cultural diversity and resilience, health, education and ecology. GNH stresses communal happiness to be addressed straight through public policies in which happiness becomes an explicit criterion in development projects. Among the achievements, guided by with GNH results, Bhutan's authorities divulge improvements in health services and of the access to primary education through a network of community schools, as well as an increase in the literacy rate as part of a broader goal of ensuring education for all citizens. Despite the criticism claiming that this model does not allow international comparison of well-being, the concept of GNH as a development philosophy has evolved into an international conscience, introducing equality and happiness as necessary variables to measure societal progress.

Different and sometimes simplified versions of the GNH concept may be found in the Gallup-Healthways Wellbeing Index and the GNH proposed by the President of the International Institute of Management, Med Jones (http://www.iim-edu.org/grossnationalhappiness/). By treating happiness as a socioeconomic development metric, this version of GNH traces seven kinds of development of wellness (economic, environmental, physical, mental, workplace, and political) via direct survey and statistical evaluation. The Gallup-Healthways Wellbeing Index assesses US residents' health and well-being. By interviewing American citizens every day, this index provides real-time measurements and obtains insights as a resource of health figures and behavioral economic data. The in-depth 2012 state report included city and congressional district level findings for each American state (http://www.well-beingindex.com).

The concern with national happiness is also spread in the social sciences. The Subjective Wellbeing of Nations (SWB) was reported for 55 nations. The SWB surveys show that high income, individualism, human rights, and societal equality are strongly correlated with each other and SWB across surveys. Cultural homogeneity and income growth comparison show low or inconsistent relations with SWB (Diener et al., 1995, 1999). Kahneman et al. (2006) reported that the relationship between having more income and happiness is extremely exaggerated. These researchers developed the 'Day Reconstruction Method,' a tool to assess people's quality of daily life, which creates an "enjoyment scale." Kahneman et al. (2006) found that people with above-average incomes were relatively satisfied with their lives but could not establish that they were happier than others with lower incomes. Arguing that the effect of income on life satisfaction is transient, they concluded that people overestimate the contribution of income to happiness. Comparisons of wellbeing and per capita GDP show that, at a certain income level, happiness does not increase significantly with additional income, and economic gains beyond a threshold no longer correlate with increases in personal wellbeing (Inglehart, 1997). Blanchflower and Oswald (2008) termed the Easterlin paradox (1974), which refers to the fact that happiness data are typically unchanged despite significant increases in income. These authors affirm that the official government statistics should match objective and subjective wellbeing data, and that sustainability must be the criterion to be applied.

White (2006) showed that there is increasing political attention in using measures of happiness as a national indicator in combination with measures of wealth and report that the nation's level of happiness is directly associated with health levels, followed by wealth and provision of education. However, contrary to these ideas, Di Tella and MacCulloch (2008) find that the happiness responses of around 350,000 people living in the OECD countries between 1975 and 1997 are positively correlated with the level of income.

The World Database of Happiness offers a compilation of studies and data related to happiness and satisfaction surveys (Veenhoven, 2013). It is an archive of research findings on subjective enjoyment of life with 7380 publications in the bibliography of happiness, of which 3579 reports on empirical studies, with 960 measures of happiness, mostly based on single survey questions varying in wording and response scale. The archive includes 5639 distributional findings from the general public in 164 nations and 1761 studies with findings in 150 specific publics. It also includes 12,562 correlational findings observed in 1695 studies that are excerpted from 1193 publications. As shown by the number of studies collected in the World Database of Happiness, there has been an increase in research on socially oriented indicators for evaluating human wellbeing based on self-reporting by individuals and groups. This type of research relates to subjective wellbeing (SWB), and is designed to correlate satisfaction with the quality of life, which depend on people's temper and emotions (Diener and Suh, 1999). Because socially oriented indicators are based on the judgments of the survey respondents rather than on quantifiable inputs of currency or material possessions, there are concerns that these subjective measures are not based in facts, and should be less valid than objective measures like GDP. There is also a concern that cultural differences make it complex to compare the results across different ethnic, gender, age, religion, and other cultural boundaries. However, objective measures such as life expectancy, rates of disease, and GDP are also proxies for wellbeing that have been identified through the personal judgment of analysts, experts and decision makers; hence, the choice remains between subjective measures and proxies (Costanza et al., 2007).

3.3. Combining social and environmental concerns

Several approaches of measuring overall progress or wellbeing have been recommended, developed, and applied in recognition that GDP disregards social and environmental well-being. Many governments and non-governmental organizations have taken the initiative and developed their own indices. Most of them are composite indexes merging different measures into a single number consisting of GDP plus social and environmental concerns.

The Wellbeing Index (WI) is based on the hypothesis that a healthy environment is essential for healthy humans (Prescott-Allen, 2001). It was used in the evaluation for the World Summit for Sustainable Development in Johannesburg 2002 and included 180 countries. The WI consists of two indices, the Human Well-being Index (HWI) and Ecosystem Wellbeing Index (EWI). HWI includes population and health parameters, community and equity issues, wealth indicators, knowledge indicators and culture while EWI aggregates land, water and air dimensions, biodiversity issues and resource use indicators. The aggregation of these dimensions is made by a weighted arithmetic mean of variables that are normalized again by a proximity-to-target approach. Both indices are given equal weight when combined into a tool called the Barometer of Sustainability.

The Happy Planet Index (HPI) was launched in 2006, by the UK's New Economics Foundation, intending to challenge existing indices, such as GDP and HDI. The HPI combines environmental impact and welfare to determine the environmental effectiveness with which people live long and happy lives, converting the earth's finite resources into well-being. It does not disclose the world's happiest country, but intends to reflect the average length of a

happy life produced by a given group per unit of planetary resources consumed. HPI uses three dimensions: life expectancy at birth, life satisfaction, and ecological footprint. The 2012 report shows the results for 151 countries that depict not only how a country ranks on the HPI scale, but also how the three components affected the ranking (Abdallah et al., 2012).

The Environmental Sustainability Index (ESI) intends to measure "overall progress toward environmental sustainability" (Esty et al., 2005). This index focuses mainly on environmental issues, but it also includes social and institutional components. The ESI consists of five components: environmental systems, reducing environmental stresses, reducing human vulnerability, social and institutional capacity and global stewardship. Each of these components is built based on various sub-indicators, which incorporate indicators of physical, biological and chemical state, as well as indicators of environmental pressures and the responses of society. Indicators and variables were chosen based on the well-established "Pressure–State–Response" environmental policy model. The issues integrated and variables used were selected through a careful analysis of the environmental literature, surveys of existing data, accurate analysis, and discussion with specialists, scientists, and policymakers (Esty et al., 2005). Complementary to the ESI that focus on the environmental dimension of sustainability, the Environmental Progress Indicator (EPI) addresses the necessity for a measure of policy performance in reducing environmental load on human health and promoting ecosystem vitality and sound natural resource management. The EPI focus on a set of environmental issues tracked throughout six policy categories for which all governments are being held responsibly (Esty et al., 2006). With a more simplified structure, the SSI (Sustainable Society Index) also combines environmental issues with economic, social and institutional components departing from 21 indicators divided into three categories: Economic, Environmental and Human wellbeing (Van de Kerk and Manuel, 2008).

WI, HPI, ESI, EPI and SSI are examples of composite indexes, which might be communicative and influential tools in helping policy and decision makers provided they were constructed using a methodology clear and transparent. However, uncertainty and methodological approaches are still foremost issues to be considered both in constructing the composite indices as well their use by decision makers. Sensitivity is of particular importance for composite indicators combining social and environmental development because these aspects may have opposite directions. If one for instance aggregates social and environmental indicators the risk occurs that a flat and insensitive indicator is obtained. On the other hand, according to Henderson (1996), single number indicators are unable to measure the multiple paths to development, and separated indicators would avoid "the GDP's oversight of simply piling outdated economic formulas on top of one another to come up with an aggregate score." A set of national indicators was shaped to establish the priorities of the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil in 1992, to supply a complete picture of societal development (UNCSD, 2001). The indicators are not integrated or aggregated, and the user must recognize the meaning of each result and determine what is important to deal. Examples of the UNCSD indicators include water quality levels for the environmental group, national education levels and population growth rates as social determinants, the number of ratified global agreements in the group of institutional sustainability, and GDP per capita for the economic sphere (UNCSD, 2001). Country profiles and national reports using these indicators have been published by many member countries since 1994.

The Canadian Index of Wellbeing establishes the measurement of a set of indicators: democratic engagement, education, community vitality, environment, healthy populations, leisure and culture, living standards and time use. In the same way, the Country Futures Indicators use separate and complementary indicators to supplement GDP. Indicators include education, health, nutrition, basic services, shelter, political participation and democratic process, child development and status of minorities, environmental pollution levels, environmental resource depletion, biodiversity and species loss, cultural and recreational resources. Following the same idea, the Calvert–Henderson Quality of Life Indicators considers economic/environmental/social trends and outcomes through a systemic approach (Henderson, 1996). The 12 indicators include energy; environment; education; public safety; national security; employment; health; human rights; income; infrastructure; leisure and housing. Each one is divided into more specific indicators, which, as a whole, would cover the information needed to achieve life quality, with a depth that, through the traditional indicators, it would be impractical. They were first published in a report in 2000 and have been maintained online since then at www.calvert-henderson.com (Henderson et al., 2000). Other similar suggestions offering multiple and separate indicators are published and applied, and among them are the Measure of America (http://www.measureofamerica.org/), the Fund for Peace's Failed States Index (http://ffp.statesindex.org/rankings-2013-sortable, the United Nations' System of National Accounts (http://unstats.un.org/unsd/nationalaccount/) and the United Nations Population Fund's State of the World Population Indicators (http://www.unfpa.org/public/home/publications/pid/12511). It is worth to point out that United Nations Development Programme website provides several means to construct one's own indicator, which can be constructed including economic, social and also environmental issues that can be analyzed that can be assessed together or separately, according to the need or desire of the analyst (UNDP, 2014).

All these indicators were developed as a suite rather than as a composite index, leaving overall understanding to the user.

4. Challenges to measure progress, welfare and wellbeing

The indicator needs to be consistent to be functional, and the underlying data must be available at the appropriate time, scale and scope. Additionally, an indicator must properly measure advancements toward the desired goals. Decision-making has become progressively more data-driven, and environmental and social research has gone too slow in this regard (Giannetti et al., 2009). Hence, because of the complexity of data sets, in particular, about the ecosystem functioning and social data disclosure, there are extensive information gaps and uncertainties, and decisions and policies are often dependent on general observations, experts' opinions and even in green slogans. Table 1 summarizes the main challenges found to construct an index that intends to go beyond GDP, although some of them can be also associated to it, and are commonly disregarded by GDP enthusiasts.

The most typical difficulties found during indices construction can be mostly related to data gathering, methodology and how to include societal issues (Table 1). Some analysts of alternative or supplementary measures argue that data and methodology issues are difficulties that lead to the use of GDP (Parris and Kates, 2003). The data-methodology difficulties are common to all indicators and can partly be managed with the improvement of techniques and technology. The social-institutional barriers may eventually be still difficult to overcome.

Some thoughts about the coverage of the indicators

In times in which progress, welfare and wellbeing are hopelessly tied to the SD, it is also a time to reflect on how indicators may help

Table 1
The main difficulties and challenges to construct an index to substitute GDP.

	Difficulties	Main challenges
Data gathering	Data-related difficulties involve the reliability and availability of the underlying data. Availability relates to the time, scale and scope of the data required, and an indicator is reliable if a change in it delivers accurate information of the change in the examined system.	Data may be unavailable at the time, scale and/or scope required. Data can be compiled at the national, state, and municipality scales and the smaller the scale, the smaller will be the dependability and timeliness of data (Costanza et al., 2009). Confidentially can limit the use of available data. Insufficient capacity for data gathering in each country for social or institutional information. Governments may conceal data related to the use of strategic reserves or the lack of human rights. Standardization for data collection may be problematic due to the number and variety of different information to be collected within different countries and cultures. Lack of regularity at which the underlying data is obtainable/available.
People gathering	People designated to choose the representative indicators composing the final index may not fundamentally agree on the relative value of one among others	• Indicators must be the outcome of various stakeholders, and the challenge begins in joining people in a global discussion regarding the relative importance of indicators' dimensions.
Methodology	Alternative proposals built on environmental or social data may be more or less reliable than GDP depending on their theoretical structure. Decisions are made on items to be chosen, how items will be measured, and how different items will be combined.	• Experts assigned to select representative variables or indicators may not concur on the nature of the variables to be chosen or on the relative importance of one indicator among others (Giannetti et al., 2009); • inclusion of measures that are considered to be subjective since they are based on surveys of individuals' perceptions of well-being • In regard to normalization and weighting, there is no generally accepted procedure. • The possibility of rather subjective weightings derived by open discussion processes among experts. • Both, normalization and weighting pose a genuine problem since they aim at the comparability of variables even though these are obviously not comparable (Böhringer and Jochem, 2007). • Normalization and weighting of indicators, which in general are associated with subjective judgments (Giannetti et al., 2009) reveal a high degree of arbitrariness.
The inclusion of societal issues/	• The social and institutional difficulties are in general based on opposition to change. A need stands for a progress index to reflect societal and cultural values	• Comprise the dominance of the growth standard, ineffective leadership, and the influence of those interested in maintaining business as usual. • Reports connecting GDP growth with improvements in human well-being, highlighting the relationship of growing GDP with economic progress, poverty eradication or employment maintenance • The interest of industries and businesses whose commercial success depends on increasing economic activity. • The corporations whose profits depend on externalizing the social and environmental costs of their operations.

mankind in the path to this somewhat confuse target. It was shown that biophysical indicators (Odum, 1996; Dincer, 2002; Wackernagel and Rees, 1996) provide information on the limits of the natural capital (carrying capacity) to be used to promote economic growth and social welfare. It was also shown that socially oriented indicators can provide valuable information on the conditions and behavior of societal development and the delicate relationship between economic growth and individuals' happiness (Ura and Galay, 2004; Kahneman et al., 2006). However, it is clear that monetary oriented indicators fail not only to measure well-being but also to specify how greater progress can be achieved. Degrowth is eminent and needed in medium-term adjusting human needs and consumption to the carrying capacity of the planet (Odum and Odum, 2006; Research and Degrowth, 2010). Fig. 1

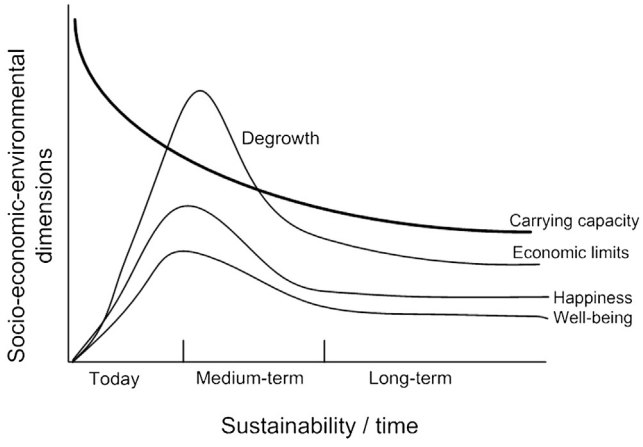
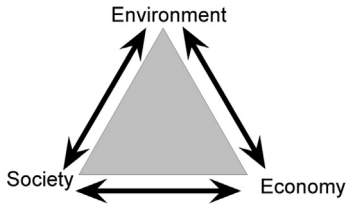
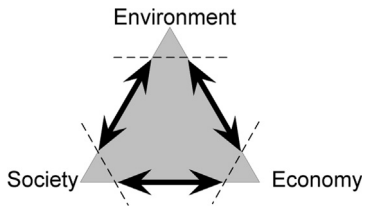
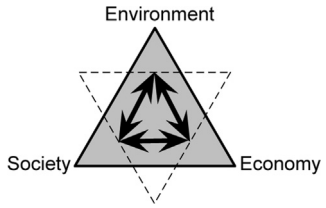


Fig. 1. Interactions among social, economic and environmental aspects.

Table 2
Weak, medium and strong sustainability models and their assumptions.

SD Model	Description
Weak sustainability 	In weak sustainability, the interaction between human and natural systems occurs through separate and unlimited compartments. The sum of all capital (environmental, economic and social) is kept constant, without differentiating the type of capital. It allows for natural resources to be depleted, so long as this depletion is replaced by increases of other forms of capital (Neumayer, 2010). Thus, indicators that add together scores on environmental and social issues make the implicit assumption that environmental and social objectives can be substituted for one another.
Medium sustainability 	In the medium sustainability, one considers the sustainability as the sum of all capital (environmental, economic and social) with a common domain area, but there are also independent areas. In this type of sustainability, the sum of the three types of capital (ecological, economic and social) is also kept constant, but exchange between different types of capital is be limited. Since the critical limits for each capital in unknown, caution is recommended to not deplete resources (especially natural capital). The medium sustainability is an improvement over weak sustainability, but its main weakness is that it is complex, if not impossible, to identify the critical limits for each capital. Indicators add scores on environmental and social indicators make the implicit assumption that substitutability among capitals is possible but limited.
Strong sustainability 	In the strong sustainability model, one considers that the environment contains human systems and provides resources (such as minerals and energy) and environmental services (such as the dispersion of pollutants). These resources and environmental services are the basis of socio-economic development and are the source of the real human prosperity. Human systems are contained in the natural system and economic and social capital cannot grow beyond the intrinsic limitations of the biosphere. Indicators under the strong sustainability perspective make implicit that the natural capital and built assets are complements (as opposed to substitutes). Only by maintaining both stocks intact can guarantee long-term economic welfare (Neumayer, 2010).

illustrates the observed situation separating the social-economic-environmental dimensions, and highlighting the problem of continuous economic growth disregarding the environmental limits. A special volume published by the Journal of Cleaner Production discuss in depth the future trends of sustainable development research and practice (Baumgartner R J. 2011).

It is clear that the carrying capacity, which can be measured by biophysical indicators, limits economic growth indicating the necessity of a degrowth (Latouche, 2010; Daly, 2013). At the local and global level degrowth refers to an equitable downscaling of consumption and production assuring human well-being and ecological conditions (Schneider et al., 2010). In the same way, the idea of a Prosperous Way Down (Odum and Odum, 2006) states that progress, wellbeing and even happiness should adapt respecting the capacity of the planet in providing resources and environmental services. The fact that developed countries cease to domestically producing basic materials (steel, aluminum, and chemicals), importing them and the manufactured goods from abroad, results in increasing emissions from developing countries and decreasing global sustainability. Thus, it is time to recognize the importance of trade in national wellbeing and progress. A proper indicator should check progress considering the nations' carrying capacity, and with a significant portion of progress and wellbeing depending on overseas trade partners, the indicator should also account the partial responsibility for the emissions growth in developing countries; inequities, migrations and poverty caused by unfair trade and unproper national policies.

Selected indicators can be associated to weak, medium and strong sustainability (Table 2), depending on how one considers the exchange between natural, economic and social of capital (Daly, 2008). Table 3 provides an overview of the main progress measurements reviewed in this paper. In particular, the table reviews and complements the advantages and disadvantages of these measures in capturing what the present research consider being key contributors to national progress towards SD.

All of the existing accounts have positive and negative aspects, including GDP, and there is still place for further development. Even if problems with GDP are recognized and many different measures have been proposed, there are still difficulties in developing, implementing, communicating and using alternative measures of progress. The ideal indicator must be projected to supply information about the system, its conditions and how its situation may change with time, thus providing information on whether national policies and programs are moving society in the right direction. Considering that the final target is SD, under strong sustainability conditions, the selection of a particular progress/welfare/wellbeing indicator must define what is meaningful for the national systems and their limits of natural, social and economic capitals (Fig. 2), and also their contribution to the global sustainability, which includes their responsibility in emissions reduction (Bastianoni et al., 2014) and in using nonrenewable resources.

The representation in Fig. 2 includes the time perspective complementing that offered by the Natural Step (TNS) framework (Robert, 2000) and those provided by Lozano (2008), with the social drivers divided into basic wellbeing (education, heath, shelter, etc.) and subjective wellbeing (happiness). At the moment, economy grows along with wellbeing and happiness at the expense of the carrying capacity. The second stage (medium-term) in the path to sustainability involves the economy degrowth, at the time that basic wellbeing is already provided to the entire society, and the curve representing happiness follows economic growth curve for a while, but falls in accordance with the results of Kahneman et al.

Table 3
Strengths and criticisms related to progress measurements and their link to the weak, medium and strong sustainability models.

Measure	Nature	Strengths	Criticisms	Link with SD model
Emergy	• Non-monetary approach • Considers the part of the gross economic product based on real wealth • It provides a clear measure of the magnitude of human activity in a particular area with respect to available ecological energy flows	• Comparable between nations. • Based on objective data. • Uses a science-based evaluation system • Treats built capital and natural capital as complements • Differentiates renewable, non-renewable and economic capitals • Provides a set of indicators and can be expressed in currency equivalents	• May indirectly account emissions and waste generation. • Lacks a clear sustainability threshold • Is a poor communication tool, of difficult understanding by the general public	Strong Sustainability
Ecological footprint	• Non-monetary approach • Index based on consumption converted in area units • It measures the hectares used to sustain lifestyles as representatives of human consumption and waste generation	• Comparable between nations. • Based on objective data. • Powerful communication tool, of easy understanding by the general public	• Provides no information on when specific ecological limits relating to ecosystem services might be reached • Do not differentiate renewable, non-renewable and economic capitals • Limits of calculations transfer all results to carbon emissions and disregards terrestrial and aquatic biomes • The method used to translate CO_2 emissions into land needs further development • Equivalence factors are not available to the general public	Medium sustainability
Gross national happiness	• Non-monetary approach. • Paradigm shift away from the GDP. • Strikes a balance between • Spiritualism and materialism.	• Based on subjective (surveys) data. • Accounts for qualitative aspects fundamental to progress. • Comprehensive approach divided into nine domains. • Powerful communication tool, of easy understanding by the general public	• Overly ambitious measure, given the current state of knowledge. • Subjective nature may lead to political manipulation. • Not comparable between nations.	Medium sustainability
United Nation's Commission on Sustainable Development	• Operates under a pressure-state response framework. • Developed to assist with national decision-making.	• Assesses environmental, economic, social and institutional indicators. • Based on objective data. • Comprehensive measure – 15 themes and 38 subthemes.	• No integration between the different indicators. • Fails to specify how greater progress can be achieved. • Leaves overall understanding and interpretation to the user. • Comparability between nations depends on data availability	Medium sustainability
Wellbeing index	• Measures welfare by adding benefits and subtracting costs. • Assumes market and welfare are not the same.	• Goes beyond the scope of the market and national accounts in assessing welfare. • Based on objective data. • Unlike GDP, the nature of the need is of concern.	• Excludes renewable and nonrenewable natural resources, due to long-run substitutability. • Under-represents human capital impact on progress.	Medium sustainability
Country futures indicators and Calvert–Henderson quality of life indicators	• Consider trends and outcomes of economic, environmental and social through a systemic approach • Provides specific indicators that cover in-depth information	• Based on objective data. • Goes beyond the scope of the market and national accounts in assessing welfare	• No integration between the different indicators. • Fails to specify how greater progress can be achieved. • Comparability between nations depends on data availability	Medium sustainability
Green GDPs	• Adjusts national accounts for the depletion of natural resources and changes in quality of the natural environment	• Comparable between nations. • Based on objective and subjective (pricing of environmental values) data. • Highlights questionable production and consumption patterns.	• Needs to emphasize other nonmonetary areas. • Depends on several methods for monetization of environmental. • Excludes social costs and distributional issues. • Results are heavily influenced by GDP figures.	Weak sustainability

(2006). Comparisons of countries sustainable development should, in fact, be replaced by the accounting of global sustainability, or by the contribution of each country to SD. The direct assessment of national indicators does not to respond fundamental questions, such as who's responsibility is unsustainability? Is it the consuming (importing), the producing (exporting) country, or both? When the intention is to assess indicators on their quality regarding countries' local wellbeing, disregarding their global impact, this issue can be

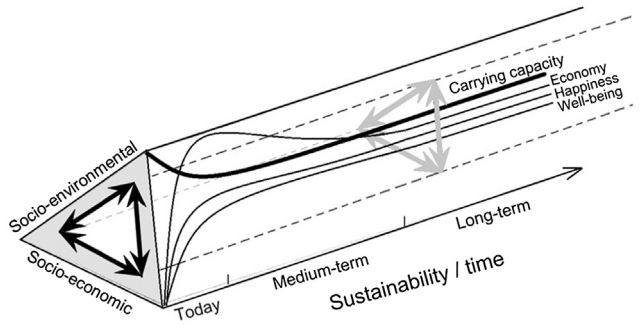


Fig. 2. Interactions among social, economic and environmental aspects within the strong sustainability framework through time.

disregarded. However, if the intention is to assess country indicators including their global impact, or to consider backfiring effects, such as GHG emissions elsewhere due to imported products or immigration and poverty elsewhere, consideration of this aspect becomes inevitable. Thus, the third stage (long-term) creates a vision of how a sustainable society would look like with basic wellbeing satisfied, a higher level of subjective well-being, and a global economy that develops within the limits of the planet. Fig. 2 illustrates the interactions of economic, environmental and social aspects, considering that sustainability is a dynamic target.

5. Concluding remarks

All attempts to measure progress have attracted criticism regarding certain valuation techniques, limitations and scope. Consequently, there is a need for a global dialogue and consensus on these issues, and there are still some questions that need help from the academic, social and political communities to be answered.

- What indicators may be used to evaluate progress towards SD?

The conventional use of the term progress comprises notions of economic and social development. However, over time, the term progress has adapted to reflect needs, and so have its measurement. In circumstances in which progress, welfare and wellbeing are intimately bound to the SD, it is also a time to ponder on the use of biophysical indicators to estimate this progress and guide human societies to SD within the limits of the planet.

- Who will select those indicators?

The various proposed indexes reviewed were not expected to be consistent as experts devoted to building them come from quite different sectors (academic, governmental, business, non-governmental, etc.) and have different expertise. Specialists, despite their specific expertise in their own area, may feel a lack of sureness, confidence or knowledge when forming an opinion on diverse subjects, and eventually personal judgment is adopted. Their weighting for environmental, economic or social indicators, may include judgments held without scientific evidence and may threaten the objectiveness of the analysis (Giannetti et al., 2009).

It is clear that the indicators must be the outcome of extensive studies, handled by multidisciplinary groups of specialists and scientists, governmental agencies, companies and nonprofit organizations, who understand the need for more efficient and advanced metrics for size up progress allied to well-being, within the planet's limits. The challenge rests on how building a measure delimiting whether societies are progressing, on what should be covered, what could be excluded, to set the standards, and how incorporate societal values into a standard. This work should start within the academic community to assure a reliable scientific basis and the rigor for data collection and treatment.

5.1. To whom those indicators are of interest?

Some suggestions are based on the notion that, provided the complexity of the problems defying humanity, a unique indicator will not be satisfactory, and that a broad set of combined indicators may be most useful at providing knowledge guiding to better policies and decision making. Though, this approach is not only more confusing to understand by the overall public, but also facilitates prejudiced or influenced interpretations driven by interests in particular areas. On the other hand, one number indicators may conceal significant aspects and are simply to be mistreated, such as GDP. Policy decisions based on macro-level checks may be worthless, and different indicators must help nations deciding if authorities are delivering the services for the prosperity people are envisioning. Thus, it seems reasonable that a proper indicator may be composed by a set of indicators for policymaking use, which can be combined in a single number for disclosure to the general public.

- How will they be measured?

The search for an alternative to GDP is not done, and conceptual and data-gathering difficulties still wait to be resolved. The shift to reliable measures of progress may be delayed by continuing debate by indicator experts, seeking for the suitable measure of progress. Though, since progress measures are an indispensable connection between the economy and the countries' policies institution, a proposal that can assure intangible variables associated to progress and wellbeing will not be overlooked. Accurate measurements of these variables are essential to the formulation of adequate policies.

The bond between policy and progress obligates the monitoring of three fundamental spheres: resources, infrastructure, and the environment, which must provide useful and readable information to decide about alternative policy options. Size and purposes are certainly critical to be defined. The sustainable capacity of a social system is associated to biophysical indicators qualified to estimate the capacity of ecosystems to restore materials and assimilate emissions. The indicator must be qualified to fix both the greatest sustainable size and global fairness in terms of resource usage. Biophysical indicators must assist deciding on the maximum size of the economy while social indicators may help determine the minimum need to be provided. This approach may help mankind to envision what progress might be in an economy that merged personal wellbeing, equality and low material wastage.

- What can be done within the possibility of the existing accounts?

The continued mistreatment of GDP as a measure of wellbeing necessitates an urgent, forceful, and enduring action to adjust the indicators that decision makers are using to guide policies and evaluate progress. As this review shows, authors have been trying to include different dimensions into cohesive frameworks, but current approaches still tend to underemphasize or overemphasize some contributions to the progress. All indicators are limited estimates. None can actually measure all significant aspects of economic, social, and environmental well-being. There is a need for agreement on developing indicators to establish policies, to guide decisions, and measure progress.

This comprehensive review shows that if mankind is concerned with strong sustainability, then indicators measured only in

monetary or social terms are quite limited. However, despite restricted to the weak or the medium sustainability model, these indexes (green or not) represent a momentous counterbalance to GDP in the measurement of progress.

The measurement of natural capital usage and depreciation is a major problem, and biophysical indicators are the only ones that can be associated to a strong sustainability model, and must be included/confronted to any progress evaluation.

Nevertheless, none of the measures discussed in this paper seems to accomplish to assess the progress towards sustainability addressing eco-system functionality and ensuring sustainable societal development. The tremendous amount of environmental, social and economic issues formulate problems that none of the already proposed measures can undertake independently in an adequate manner. The ideal index(es) should provide a complete description of how the economic system fits within and environmental systems while attends the social demands. Thus, because no single measure can cover the full range of perspectives, the use/combination of different approaches should be the subject of future research.

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