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The argument against a reductionist approach for assessing sustainability

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ABSTRACT

Both sustainability and sustainable development continue to remain elusive concepts even now, 20 years after the Brundtland Commission report that brought them into prominence. There is no consensus over their definition. This situation most likely stems from the fact that sustainability science encompasses the need to address a wide set of issues over different time and spatial scales and thus inevitably accommodates opinions from diverse branches of knowledge and expertise. However, despite this multitude of perspectives, progress towards sustainability is usually assessed through the development and utilisation of single sustainability metrics such as monetary models, composite sustainability indices and biophysical metrics including emergy, exergy and the ecological footprint. But is it really justifiable to assess the progress towards sustainability by using single metrics? This paper argues that such a choice seems increasingly unjustifiable not least due to these metrics' methodological imperfections and limits. Additionally, our recent awareness of economies, societies and ecosystems as complex adaptive systems that cannot be fully captured through a single perspective further adds to the argument. Failure to describe these systems in a holistic manner through the synthesis of their different non-reducible and perfectly legitimate perspectives amounts to reductionism. An implication of the above is the fact that not a single sustainability metric at the moment can claim to comprehensively assess sustainability. In the light of these findings this paper proposes that the further elaboration and refinement of current metrics does not seem sufficient to produce frameworks for comprehensive sustainability assessments. Adoption of diverse metrics seems more likely to be the key for more concrete sustainability assessments. This methodological pluralism coupled with stakeholder involvement will most likely culminate in better informed policy making.

Key words: sustainability assessment, sustainability metrics, reductionism

1 INTRODUCTION

Governmental bodies, non–governmental organisations, academics and the public are engaged worldwide in policy discussions trying to envision and operationalise a development path that can meet the needs of present and future generations in an equitable manner. The goal of increasing the economic welfare of a population over time is not a new policy objective. However, the acceptance during the past two decades that the state of the environment and the functioning of society are equally as important has led to the formulation of more elaborate policy questions. The desired development path that ensures the economic welfare of present and future generations by further considering environmental and social issues has come to be known as Sustainable Development and was brought into prominence by the Brundtland Commission (WCED, 1986). Even though there is no universally accepted clear cut definition of the term there is a consensus that economic, environmental and social issues together with intragenerational and intergenerational equity ought to be considered within the framework of Sustainable Development (Pezzoli, 1997).

Measuring Sustainable Development and quantifying the progress towards sustainability is currently at the centre of an ongoing debate that progressively moves beyond the academic sphere. A number of different methodologies for its assessment have been proposed but very few if any seem to be able at the moment to be able to assess sustainability adequately in a holistic manner.

The majority of the widely used sustainability assessment methodologies fall within three major categories: monetary tools, biophysical models and sustainability indicators/composite indices. In all three a similar procedure of initial evaluation/quantification of the diverse environmental/economic/social issues and subsequent aggregation is pursued. The positive or negative contribution towards Sustainable Development objectives is then highlighted either by comparing the output of the sustainability assessment with a certain benchmark or through the ranking of different options in respect of their sustainability (i.e. ranking the options in respect of their fulfilment of sustainability criteria) or in some cases through both.

Monetary tools have formed the backbone of most sustainability assessments especially for policy making. The majority of the most commonly used monetary tools were not conceived specifically for sustainability assessments but were rather developed and matured before the Sustainable Development debate erupted. Examples include evaluation tools such as the Contingent Valuation Method (CVM) and aggregation tools such as Cost Benefit Analysis (CBA). The adaptation of already existing monetary tools to assess the progress towards sustainability had the great advantage of their strong theoretical foundations in economic theory. However, it soon became obvious that such monetary tools are inadequate in certain situations as progress towards sustainability goes beyond economic efficiency to include equity considerations. Another concern arose through the monetisation of certain environmental and social issues with several criticisms targeting the methodological, conceptual and philosophical aspects of the monetisation procedures adopted.

Such criticisms indicated the necessity for the development and utilisation of tools with solid foundations in the natural sciences that can more reasonably quantify environmental issues (Ecological Economics, 1999; Munasighe and Shearer, 1995). Numerous such methodologies, some more and some less comprehensive have been developed. The most comprehensive (i.e. those that are able to address a relatively large number of sustainability issues) include the ecological footprint, emergy synthesis and exergy analysis. However despite their potential and alternative viewpoint most biophysical tools have yet to enter the mainstream.

Currently there is an active interest in sustainability indicators/composite indices judging from the large number of sustainability indicator lists published by academics, local authorities, national and international organisations (Prescott-Allen, 2001; UN, 2001; Esty et al., 2005). Such lists contain indicators that capture sustainability issues relevant to the context of the specific assessment exercise. The indicators are subsequently being aggregated to a single composite index or left disaggregated according to the intentions of the analysts. Aggregation choices are usually a trade off between loss of information when aggregated and fuzziness when disaggregated.

The advantage of comprehensive tools as the ones referred to in the previous paragraphs lies in the fact that they can reduce and integrate the diverse issues affecting progress towards sustainability to a small set of numbers. Such tools can be invaluable to policy makers as they can summarise a large volume of information to non-experts. However methodologies must be accurate, robust and based on sound theoretical foundations backed with empirical evidence in if misleading policy messages are to be avoided. With these prerequisites in mind, this article seeks to determine whether it is possible to capture sustainability with a single metric.

2 CONTEXT OF SUSTAINABILITY ASSESSMENTS

Before attempting to answer this question it is useful to understand and appreciate the context within which sustainability assessments are performed. Of particular relevance are the insights deriving from two new paradigms; complexity theory and post-normal science.

Complexity theory seeks to understand and shed light on the mechanisms governing systems which are usually the focus of sustainability assessments. Ecosystems, economic sectors, societies and even cities are considered as complex and adaptive whose "*…properties are not fully explained by an understanding of their constituent* *parts*" (Gallagher and Appenzeller, 1999). Completely understanding the constituent parts of a complex adaptive system does not allow a complete description of it because the interrelations between its parts also have a significant effect on its overall behaviour; the progress towards sustainability in our case. To express this in an easier manner the whole system is greater than the sum of its parts. A key characteristic of complex systems is their dynamic and non-linear nature where the existence of feedback loops renders the prediction of their future behaviour very difficult because small inputs can lead to dramatically large consequences (butterfly effect) (Lewin, 1999). A second characteristic that renders their study even more problematic is their tendency to be nested. For example, human societies are complex adaptive systems which are in turn embedded in more complex adaptive ecosystems (Limburg et al., 2002).

Post-normal (not to be confused with post modern) science is concerned with the decision making process especially in situations where facts are uncertain, values in dispute, stakes high and decisions urgent (Funtowicz and Ravetz, 1993). Central to post normal science are the needs to manage uncertainty and to accommodate different perspectives and ways of knowing (Funtowicz and Ravetz, 1993). Funtowics and Ravetz (1994) have argued that that as a result of emergent complexity *"…No single perspective from within a subsystem of fewer dimensions can fully encompass the reality of the whole system….(a)lthough legitimate in its own terms cannot be sufficient for a complete analysis of its (the system's) properties".* As a result one can argue that no single legitimate perspective can provide a comprehensive or adequate vision of an issue (progress towards sustainability in our case) and indeed it would not make sense to exclude all other legitimate perspectives in favour of one.

3 METHODOLOGICAL LIMITS

3.1 Monetary tools

There is an overwhelming weight of literature commenting on the use of economic analysis for sustainability assessment e.g. (Neumayer, 2004; Pezzey and Toman, 2002; Goldin and Winters, 1995; Pearce, 1993a). For the purpose of this paper only key ethical and methodological criticisms of certain commonly used monetary tools will be discussed in order to explain both the limits of economic valuation/aggregation and the discontent that has arisen over the validity of economic analysis in sustainability assessments.

The root of these criticisms probably stems from the fact that the most widely used valuation and aggregation tools such as Contingent Valuation Method (CVM) and Cost Benefit Analysis (CBA) were not developed specifically for sustainability assessments but were rather arbitrarily adapted for such purposes. These tools have their methodological foundations in the neoclassic economic view of humans as economic persons.

Ethical criticisms have provided some of the most telling arguments against the monetisation of environmental and social issues in sustainability assessments. Heinzerling and Ackerman (2002) comment on the fact that respondents in CVM surveys are asked to give their preferences as individual consumers rather than as citizens living and acting within the society. Sagoff (1998) provides examples where the elicited monetary values in CVM surveys are different when respondents assume different roles (consumer vs. citizen) or consider others in their response (individual vs. individual considering others as well). Furthermore according to Bebbington et al. (2006) monetisation of certain environmental and social sustainability issues (e.g. biodiversity, human health etc) can be seen as morally questionable since it might be argued that it devalues these issues by bringing them to a position where they can be compared with other monetised issues and thus be substitutable with them. For example in an investment decision high gains in economic output might offset loss of biodiversity or detrimental effects in human health as a result of increased pollution. This compensability and subsequent substitutability of monetised values are essentially trade offs between sustainability issues within monetary tools and form the core of the debate of strong vs. weak sustainability, e.g. (Neumayer, 2004).

Methodological criticisms show even more strongly and undisputedly the limitations of economic tools for sound sustainability assessments. Venkatachalam, 2004 exposes a string of methodological issues that affect the validity and reliability of a CVM study. Issues such as discrepancies between elicited Willingness To Pay/Willingness To Accept (WTP/WTA) values, provision of information and strategic responses by the respondents, amongst others, cast doubt on the validity of the elicited monetised values. Knowledge of the valuation context and objective judgement on the part of the respondent is also assumed. Costanza (1991), as quoted in Patterson (1998), comments on the dangers arising from that assumption by exposing a number of biodiversity evaluations where consistently higher values were elicited for species with which respondents could empathise such as mammals (dolphins, pandas etc) when compared to other species such as invertebrates. Similar criticisms can be found in the literature and for other commonly used valuation techniques such as the Travel Cost Method, Hedonic Price Method, etc (Pearce, 1993b). An immediate outcome of this is that monetised values fed into aggregation tools such as CBA might be highly uncertain at best or in some cases not make sense at all.

Aggregation of monetised values raises new questions on whether the procedures adopted are in accordance with Sustainable Development considerations such as equity. When aggregating monetary values, CBA analysts tend to use the Kaldor-Hicks criterion that allows for a project/policy to be undertaken if the size of the resulting benefits is high enough for the gainers to compensate in theory the losers, though the compensation would not have to be actually carried out (Brent, 1996). This theoretical compensation seeks to safeguard the welfare of society by allowing a project/policy to be undertaken even if some social actors lose, and are not compensated, provided that the society gains as a whole. Consequently, it would make perfect economic sense to adopt a development path which would favour better off sections of the society as long as their overall net benefits are higher than the net costs that might be suffered by poorer sections especially when adequate compensation might not actually take place. But this is hardly an equitable situation. According to Munda (1996) a hidden assumptions of the Kaldor-Hicks criterion is its treatment of the marginal utility of a unit of additional income as the same for all social actors something that is rarely the case e.g. (Layard, 2005). According to Zerbe et al. (2006), the current version of the Kaldor-Hicks criterion is characterised, amongst others, by the fact that equity effects are disregarded while it is devoid of any ethical justification (Layard and Glaister, 1994). Thus, applicability of the Kaldor-Hicks criterion for intragenerational and intergenerational settings has been questioned e.g. (Azar, 2000). Another issue, this time concerned with intergenerational equity, is that of discounting or in the other words the procedure pursued to render future costs/benefits comparable with present costs/benefits. Positive discount rates, however small, tend to strongly devalue distant future costs/benefits resulting in almost ignoring them for projects/policies with long time horizons such as those expected to span over different generations. This can be perceived as contrary to the interests of future generations. Certain economists hold the view that because CBA is rooted in the concept of economic efficiency issues of intergenerational equity cannot and should not be addressed by the CBA alone (Goulder and Stavins, 2002). Taking this rationale a little bit further one can reason that notions of intergenerational equity cannot be addressed by explicit choices of an "optimum" discount rate (whether this rate is low or zero) but instead must be addressed by other means that fall outside the scope (economic efficiency) of the CBA. Nevertheless, a different faction believes that economists must provide policy makers not only with information on economic efficiency but include in their analyses additional policy questions such as equity considerations (Sumaila and Walters, 2005). Modifications of the current discounting and aggregation procedures have been proposed by Rabl, (1996), Farrow (1998), Padilla (2002), Sumaila and Walters (2005), Saez et al. (2006) and Zerbe et al. (2006).

3.2 Biophysical models

As already mentioned biophysical models aim to quantify aspects of Sustainable Development through a natural science perspective. Such quantifications seem to be more "objective" and accurate especially when it comes to environmental issues as they do not depend on human preference but on biophysical parameters that can be precisely measured. Of the large number of biophysical sustainability measures only a handful has been developed to capture several sustainability issues. Three such metrics that have gained some acceptance between academics include emergy, exergy and the ecological footprint. Of these only the ecological footprint seems to have escaped from academia by being adopted, to a limited degree though, mainly by NGOs and a few policy makers.

Emergy and exergy account for the different material/energy/etc flows within a system. Despite their different scopes they share the same assumptions that in every observable phenomenon there is energy transformation and that all energy transformations within a system can be accounted for with a common denominator: embodied solar energy in the former case and available energy or exergy in the latter case. The ecological footprint quantifies the total area of productive land and water ecosystems required to produce the resources that the population consumes and assimilate its wastes (Rees and Wackernagel, 1996). According to Wackernagel et al. (1999) the ecological footprint methodology assumes that it is possible to keep track of all the materials and human services required to sustain a human population and assimilate its wastes by converting most of them to a corresponding biologically productive area. Since different productive lands produce different commodities and to differing degrees a common currency, the global hectare (gha), was developed.

However some methodological limitations raise questions over the validity of biophysical measures. One of the most important limitations is relevant to the allocation rules. In particular the allocation of multiple products of a process as co-products or splits can influence the results of the analysis to a great extent and has yet to be resolved in an acceptable manner (Hau and Bakshi, 2004). Such problems are common to all tools that follow procedures similar to that of the Life Cycle Assessment (LCA) which is the case for emergy, exergy and the ecological footprint in particular (Simmons et al., 2000).

A second problem arises from the data intensive nature of the biophysical models. Biophysical models usually require a large number of detailed data sets in order to accurately account for the metabolism of the system under study. In certain cases and in urban systems in particular these data are usually not recorded or are conflicting at best.

Integral parts of emergy synthesis (solar transformities), exergy analysis (chemical exergies of substances) and the ecological footprint (equivalence/yield factors) have been calculated under very specific and restrictive assumptions. For most sustainability assessments these underlying assumptions are not the same (e.g. reference environment, transformities of global processes, bio productivity of land etc) so it is not appropriate to utilise standard values. However, for the sake of consistency and simplicity such standard values are used freely by analysts because in most cases recalculating them is a prohibitive task (effort and money consuming) and it may not render the results comparable with other case studies.

As a result, biophysical models despite having been developed as a result of the need for more "objective" sustainability assessment tools require a fair amount of assumptions and simplifications on the part of the analyst. Thus uncertainties that affect the quality of the final sustainability assessment are unavoidable. Biophysical models usually tackle ensuing uncertainties quite well in small scale sustainability assessments (better data, more sensible designation of a reference environment etc) but they fail to do so in larger scales such as cities and regions. According to Sciubba and Ulgiati (2005) as the scale is expanded, higher order terms and perturbations may become predominant with the system's dynamics being no longer linear and resulting in increased uncertainty.

Furthermore biophysical tools tend to quantify only but a few of the social issues that are deemed important for the progress towards sustainability, e.g. (Gasparatos et al., 2006; Wackernagel et al., 2005).

Other important methodological limitations have been discussed in several publications including (Brown and Herendeen, 1996; van der Bergh and Verruggen, 1999; Cleveland et al., 2000; Ecological Economics, 2000; Herendeen, 2004; IVM, 2002; Mansson and McGlade, 1993; Cleveland, 2005; Sciubba and Ulgiati, 2005; Valero, 2006).

3.3 Sustainability indicators/composite indices

Sustainability indicators and Composite Indices (CI) have become central to the sustainable development debate. Nardo et al. (2005a), have developed a generic procedure for the development of composite sustainability indices. Of the different methodological steps the principal ones that seem to affect the quality of the final index and consequently have faced the greatest criticism are the weighting of the indicators and their subsequent aggregation.

Nardo et al. (2005a,b) comment on the strengths, criticisms and methodological limits of a variety of tools utilised for the designation of weights in composite indices. However Munda and Nardo, (2005a) have shown that weights do not always retain their status as value judgements within a composite index. That is particularly evident in composite indices utilising linear aggregation where the assigned weights end up gaining a trade-off status that implies complete substitutability between the indicators of the composite index. In other words in a composite index constructed following a simple weighing and linear aggregation procedure higher performance of an indicator (e.g. economic output) has the ability to compensate for lower performance of other indicators (e.g. depletion of natural resources). The substitutability between the components of the CI implies the existence of trade-offs and renders aggregated CI weak sustainability tools. A comparative study by Zhou, et al. (2006) between three commonly used aggregation techniques (additive weighting, weight product, weighted displaced ideal) concluded that in most cases the geometric aggregation technique results in the minimum loss of information. It is also worth mentioning here Arrow's impossibility theorem ruling out the existence of a perfect aggregation technique for ranking alternative options (e.g. alternative designs, policies etc) (Arrow, 1963) as quoted by Munda and Nardo, 2005b.

4 CONCEPTS OF VALUE

Past studies have commented on the implications arising from the utilisation of different concepts of value in ecological economics (Patterson, 1998) and ecosystem service valuation (Winkler, 2006; Ecological Economics, 2002). However, similar implications arising in sustainability assessments have not attracted significant attention.

Biophysical and monetary sustainability assessment methodologies employ radically different concepts of value that share several similarities with the two concepts which Adam Smith pioneered and had problems reconciling. According to Smith (1986) the value of a commodity can be a proxy for either the amount of labour embedded in it or the quantity of labour (embedded in other goods) for which it can be exchanged in the market. The former is an objective measure while the latter is more of a subjective one usually depending on the needs, wants and preferences of the buyer and seller. Patterson (1998) states that Adam Smith's initial observations paved the way for the development of two distinct and at times conflicting concepts of value that have subsequently been employed in economics; the "cost of production theory of value" and the "subjective preference theory of value" having to do more with the exchange value of a commodity. Glimpses of these two concepts are evident within the various sustainability assessment methodologies.

Biophysical sustainability assessment methodologies essentially account for how much energy/matter etc has been invested for the production of a product or a service whether that is a commodity or a "free" ecosystem service. Certain biophysical methods such emergy synthesis (Odum, 1996) and Extended Exergy Accounting (EEA) (Sciubba, 2003) have moved a little bit further by accounting for monetary flows and labour inputs within an economy in biophysical terms. But whatever flows are considered, biophysical methodologies essentially answer the same question "what and how much of it has been invested for the production of a commodity/service". This is similar to the cost of production theory of value. This observation is further justified by the tendency of biophysical models to neglect human preferences (Winkler, 2006; Cleveland et al., 2000).

Monetary methodologies on the other hand tend to focus on consumer preferences. More specifically monetary techniques quantify and account for the utility that a person is expected to gain from consuming a product/service with people tending to favour the consumption of a product/service that increases their marginal utility. Utility is still not considered a cardinal (i.e. directly measurable) quantity in monetary models despite the belief of John Stuart Mill and other classical and contemporary economists and psychologists to the contrary Layard (2005). According to Farber et al. (2002) in neoclassical economics value is determined by marginal utility and the fact that consumers allocate money optimally across different uses resulting in the marginal utility for an individual to be the same for all its uses. However, monetary tools whether they capture use or non-use, market or non-market values they essentially measure a person's Willingness To Pay (WTP) for the consumption of a commodity or its Willingness To Accept (WTA) to forfeit consumption of a commodity. WTP and WTA can in turn be considered proxies of the effect on a person's utility. Despite the fact that certain of these choices are contested from the new science of Happiness (refer to Layard (2005)), the fact remains that the underlying concept of value is purely subjective as it mirrors a person's needs and preferences. In that respect the concept of value in monetary analyses is closer to Patterson's (1998) designation of subjective preference theory.

An implication of the above is that biophysical and monetary tools assess the progress towards sustainability from different and in some cases conflicting perspectives. One such illustrative example is the case of organically and conventionally grown food. Organic cultures utilize less fertiliser and pesticide than conventional cultures so in a biophysical assessment organic food will have a lower value of cost of production because fewer natural resources have been invested per unit of product. On the other hand organic food usually has higher price in the market place (higher WTP) than conventionally grown food which implies a higher value of subjective preference.

As a result adoption and utilisation of a specific sustainability assessment methodology is implicitly a choice of value system which in turn is inherently a choice of perspective.

5 IS IT REALLY POSSIBLE TO CAPTURE SUSTAINABILITY WITH A SINGLE METRIC?

Considering the previous findings the answer seems to be no. First of all the approaches discussed earlier tend to be based on reductionistic principles.

Applicability of a reductionist approach has been criticized both for understanding complex systems and for offering sufficient policy recommendations to facilitate the progress towards sustainability. Complexity theory contemplates complex systems as irreducible while post normal science emphasises that *"…to take any particular perception, or projection onto subspace, as the true, real or total picture, amounts to reductionism" (*Funtowics and Ravetz, 1994).

Evaluation of the plethora of sustainability issues is problematic given the great scientific uncertainty and ignorance in many relevant fields of the environmental and social sciences, the subjective nature of monetary valuations and the considerable uncertainties of biophysical models especially when the scale of the sustainability assessment is extended (e.g. urban, regional etc). Furthermore important information is lost during the subsequent aggregation of the different sustainability issues. In certain situations aggregation through monetary tools and composite indices imply compensability and substitutability between different sustainability issues leading to weak sustainability evaluations that might not always be desirable.

As already shown in Section 4 biophysical and monetary tools make use of different concepts of value; cost of production in the former case and subjective preference in the latter case. As a result these tools can answer different questions that fall within the scope of Sustainable Development. For example biophysical tools can quantify in an objective and meaningful manner the present consumption patterns of natural capital indicating whether the limits to growth and the operational principles of Sustainable Development designated by Daly (1990) have been breached. Moreover they can give information on the availability of natural capital to future generations assuming different development scenarios as well as the current accessibility of different social groups to it. They can also account directly or indirectly for the "free" ecological services, their contribution to human economy and the effect on it if their functioning is compromised. On the other hand monetary tools through their subjective valuation provide information on economic efficiency, economic growth and the economic welfare of a population. They are also a proxy for human preferences given the fact that they account for WTP/WTA that are in effect proxies of the effect on a person's utility. As a result it can be argued that both monetary tools and biophysical models get complementary snapshots (ecocentric vs. anthropocentric) of the progress towards sustainability but not the whole picture. Tools falling within the two categories offer two legitimate perspectives for sustainability assessment and it would be not appropriate to exclude any of their findings in favour of the other as discussed in Section 2. Furthermore Patterson (1998) commented that choice of a single theory of value might foreclose other methodological options and can be seen as reductionistic while he refrained from proposing a "*…monolithic approach based on a single value*".

In the light of these findings it is proposed that the further elaboration and refinement of current metrics does not seem enough to produce frameworks for comprehensive sustainability assessments. Elaboration of the tools without deep restructuring of the underlying assumptions will most certainly not result in more holistic sustainability assessment tools. As a result adoption of diverse metrics seems more likely at the moment to be the key for more concrete sustainability assessments. Methodological pluralism, knowledge of the limitations and assumptions of the adopted sustainability assessment tools coupled with stakeholder involvement thus bringing together different ways of knowing is envisioned to culminate in better informed policy making.

6 CONCLUSIONS

Assessing the progress towards sustainability requires the consideration of a plethora of economic, environmental and social issues and equity. At the moment none of the current popular methodological proposals seems to be able to encompass all these considerations simultaneously. Methodological limitations, different concepts of value and new insights from complexity theory and post-normal science leave little room for believing the contrary. In answering the question posed earlier we believe that assessing the progress towards sustainability in a holistic manner is a very difficult task that seems impossible at the moment. Attempting to assess the progress towards sustainability by using a single metric is likely to send misleading policy messages. As a result methodological pluralism as advocated by Norgaard (1989) coupled with stakeholder involvement seems a safer path to tread.

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