Rediscovering the Condorcet approach as an aggregation technique for progress measures

Natoli, Riccardo and Zuhair, Segu (2011) Rediscovering the Condorcet approach as an aggregation technique for progress measures. Economic Papers, 30 (3). pp. 368-376. ISSN 0812-0439

REDISCOVERING THE CONDORCET APPROACH AS AN AGGREGATION TECHNIQUE FOR PROGRESS MEASURES

by

Riccardo Natoli and Segu Zuhair[1]

There are three main aggregation techniques designed for progress measurements to help facilitate the benchmarking and ranking of countries according to aggregated dimensions. They are: (i) *additive methods*; (ii) *geometric aggregations*; and (iii) *non-compensatory multi-criteria analysis*. Virtually all measures utilise one of the first two techniques. This paper will critically review the above aggregation approaches. In doing so, this paper will assert that the Condorcet approach, despite being overlooked by many major institutions, demands strong consideration for aggregating progress measures. The theoretical implications of using the Condorcet method will be explored. An empirical application of the Condorcet model is undertaken on the resource-infrastructure-environment (RIE) index to test the validity of this approach as an aggregation technique for progress measures.

Keywords: progress measurement, aggregation, Condorcet method.

JEL Code(s): O1; I32

[1] School of Accounting and Finance, Victoria University
Correspondence: Riccardo Natoli, Research Fellow, Financial Education Research Unit, Victoria University, Melbourne 3000, Australia. Email: riccardo.natoli@vu.edu.au

1 Introduction

In recent times, much research and literature has been spent on ways in which to develop a progress measure that can truly be reflective of the society in which we live in. These measures have had the objective of acting as an instrument to identify areas where policies can be developed to help facilitate optimal outcomes for national progress. However, in spite of the voluminous research undertaken in this area little focus has been paid to progress measurements that utilise aggregation techniques. A popular method of aggregation, referred to as the additive method, simply sums up the values of the components. These additive techniques range from summing up country rankings in each indicator to aggregating weighted normalised indicators. Yet, this type of method results in many restrictions being placed on the nature of the indicators and its interpretation and verification (Munda and Nardo, 2005a).

The abundance of the additive approach is best exemplified via the number of 'main' progress measures that employ its technique. Examples include the Environmental Sustainability Index (ESI), Human Development Index (HDI), the Human Poverty Index (HPI), Index of Sustainable Economic Welfare (ISEW) and the Genuine Progress Indicator (GPI). Other aggregation methods, such as multiplicative, or geometric, approach have been developed and successfully applied in the literature. Another approach, the non-compensatory multi-criteria analysis, has not been given the recognition it deserves despite its merit.

The purpose of the present paper is threefold:

(i) to review currently used techniques;

(ii) to identify the most appropriate aggregation technique for use in progress measures; and

(iii) to demonstrate the application of the Condorcet model as an aggregation technique for the resource-infrastructure-environment (RIE) progress measure.

2 Aggregation Techniques – A Review

As was outlined in the Introduction section, when progress measures employ an aggregation technique most opt for the additive aggregation method.

2.1 Additive Aggregation

Additive methods can be a simple additive aggregation which merely sums the country's rank in each of the indicators, based on ordinal information or one can use nominal scores that possess ordinal characteristics to calculate how many indicators lie above and below a designated threshold, and obtain the difference. Both approaches are simple to use and insensitive to outliers, however they make no ratio or interval level analysis respectively (Nardo et al., 2005b; Munda and Nardo, 2005a).

The most commonly used additive approach is the linear aggregation method. It is however, a restrictive technique with regard to the form of the variables. Specifically, this surrounds the quality of the variable and the measurement unit which should be the same. An additive aggregation function is said to exist only when indicators are preferentially independent. This requirement of independence, which is itself a difficult condition to achieve, suggests that assessments are made at the variable's marginal levels. These are then added to determine a total value. It also implies full compensability, allowing poor performances to be offset by good performances in other indicators (Nardo et al., 2005b; Munda and Nardo, 2005b). This technique exacerbates full compensability, which leads to rewarding exceptional behaviour and masking poor performance in certain areas.

For example, the HDI employs an additive aggregation approach (arithmetic mean) to determine its HDI value. This approach sums the country's rank in each of the indicators based on ordinal information. According to Desai (1991), the additive nature of the HDI is hardly desirable or appropriate since it implies perfect substitution between health, education and income. As Sagar and Najam (1998) point out, the fact that deficiencies in one dimension can be accounted for by a strong performance in another is far from an ideal trait for an indicator purporting to represent human development. In fact, the employment of an arithmetic average reduces the essentialness of obtaining good performances in all three dimensions. This trade-off reflects a reductionist viewpoint and seems to be counter-intuitive to the United Nations Development Programme's own definition.

Ideally, a nation's level of human development should depend on progress in all three dimensions. Here, a poor performance in one of the components should be reflected in the overall HDI value, and conversely, a good HDI value would depend on solid performances in all dimensions concurrently (Sagar and Najam, 1998). Studies from McGillivray and White (1993), Dijkstra and Hanmer (2000) and Cahill (2005) demonstrate that the HDI's capability approach alone is not sufficient in capturing the progress concept. Since most of the information about the HDI is captured in *per capita* GDP. This strong positive correlation outcome brings into question just how much additional information the HDI measure conveys regarding progress.

Additive (linear) aggregation also seems inadequate when the concept of importance is attached to the qualitative aspects of the variable rather than its quantification. For example, if protected species are perceived as more, equal or less important than GDP, this perception is a function of the quality of variable that is independent of any measurement scale one may use (Munda and Nardo, 2005b). Thus interpreting weights based on importance, when depending on a range of variable scores as the linear aggregation method does, is completely inappropriate (Anderson and Zalinski, 1988). Given its full compensability nature, it is considered to be an inappropriate aggregation technique to employ for progress measurement.

2.2 Geometric (Multiplicative) Aggregations

In geometric aggregation techniques, weights are expressed as trade offs in a manner similar to that in additive techniques. However, the variables need not possess the same measurement unit. In fact, weighted geometric aggregation is ideal for data that is strictly positive with different ratio-scales which include many environmental variables (Ebert and Welsch, 2004). Although less compensatory than linear aggregation, an absence of conflict amongst the variables is still preferred.

When deciding upon a viable approach to aggregation the consideration of the data is an essential prerequisite. Given that the data being assessed is ratio scale noncomparability, the options available are quite limited. According to Ebert and Welsch (2004), if all the variables possess a natural origin and the corresponding observations are strictly positive, then a weighted geometric mean of the crude (i.e., unnormalised) data can yield a meaningful index.

Interestingly, when Bohringer and Jochem (2007) reviewed eleven sustainability indices that possessed ratio scale noncomparability scaled variables (of which the HDI was one of them), the Living Planet Index was the only index to use the geometric aggregation procedure set out in Ebert and Welsch's (2004) article. Bohringer and Jochem, (2007) also noted that the indices failed to take into account the scientific rules for aggregation. Instead, most indices were politically desired containing inherent inconsistencies and biases resulting in either useless or misleading policies being derived from them. The HDI, with its use of an arithmetic mean, is one of these misleading indicators cited in the study.

Not content with merely highlighting the flaws in the HDI aggregation approach, Sagar and Najam (1998) proposed a re-evaluation of the calculation scheme based on a multiplicative scheme. This alternative approach, with the intention of focusing on the more vulnerable segments of society, used the product of the variables rather than an arithmetic average of the components. Under this scenario, the greater the deprivation of a dimension the more difficult it is to obtain a high HDI value since the approach is more responsive to advances in low-performing dimensions than high-performing ones.

However, employing a geometric aggregation does not necessarily remove the compensability problem since it also contains a degree of compensability between the different dimensions. According to Gasparatos, El-Haram and Horner (2008), the compensability under the geometric approach was not as damaging as the arithmetic mean aggregation employed by the HDI.

Normally when assigning weights, more weight is given to an indicator considered being of more significance to the index. Crucially, as Munda and Nardo (2005b) claim, this approach is not reflected with either the linear or geometric application. This is due to the use of substitution rates. For example, when variables are expressed as intensities, substitution rates are employed that are equal to the weights of the indicators up to a multiplicative coefficient. Consequently, weights reflect the substitution rate as opposed to the variable's importance. This leads to a compensatory logic. Thus, a poor result in one dimension can be counterbalanced by an above average result in another dimension.[2] This

[2] This substitution rate dilemma is found in most environmental impact assessment studies where most aggregations follow the linear rule and weights are attached according to their relative importance idea. Here, the ecosystem

trade-off is theoretically inconsistent to the notion of assigning weight based on their importance to the measure's objective.

According to Podinovskii (1994), a composite indicator (CI) that intends to employ differential weights to variables based on their importance needs to adopt a non-compensatory aggregation procedure. This not only avoids complete compensability, but also implies a theoretical guarantee that weights are used with the meaning of symmetrical importance where variables are used with an ordinal meaning (Munda, 2005; Bouyssou, 1986). Thus, if the symmetrical importance of variables interpretation needs to be retained then a non-compensatory aggregation procedure must be used. This can be achieved using a non-compensatory multi-criteria analysis (Condorcet approach).

2.3 Non-Compensatory Multi-Criteria Analysis – The Condorcet Approach

The Condorcet approach acknowledges that conflict exists between variables and tries to resolve it. It does this by employing a discrete multi-criteria approach that incorporates the lack of preference independence (Munda, 1995; Roy, 1996). Here, a pair-wise comparison of countries across all indicators is performed. This is then ranked from best to worst in a complete pre-order by a mathematical formulation (Condorcet-type of ranking procedure).

Under the Condorcet approach, weights are never combined with intensity of preferences - such as distance to leader. This approach, while preserving the theoretical importance of the coefficients, also minimises the degree of compensability associated with aggregation models. Given that summation of weights equal one, the pair-wise comparisons can be synthesised in an outranking matrix which can be conveniently interpreted as a voting matrix (Munda and Nardo, 2005a). This property of the Condorcet approach is a significant strength over the alternatives.

In addition to overcoming preference dependence and trade-offs, this method also allows the joint use of both qualitative and quantitative information. It also does not require any normalisation procedure since it can handle incomparability of data; something that normalisation cannot overcome (Nardo et al., 2005a).

Thus, as Munda (2005) points out, a linear or geometric aggregation is not suitable if an increase in economic performance cannot compensate a loss in social cohesion or a worsening in environmental sustainability. Instead a non-compensatory multi-criteria approach, due to its ability to find compromises between two or more legitimate goals, could assure non-compensability. Furthermore, from a social choice point of view employing non-compensatory rules (which are always Condorcet consistent) can be clearly corroborated via social choice literature. This states that desirable ranking procedures using ordinal information are always of a Condorcet type (Arrow and Raynaud, 1986; Moulin, 1988; Munda and Nardo, 2005b). In fact, Arrow and Raynaud (1986) state that for aggregating an algorithm the highest feasible multi-criterion ranking must be Condorcet.

is viewed as not being in conflict which appears to be quite an unrealistic assumption for a study to make (Funtowicz, Munda and Paruccini, 1990).

Surprisingly, Munda adds, this technique has almost never been explored in the framework of a CI. Unlike linear aggregation, Condorcet aggregation has no limitation on the measurement scale of the variable scores that exist, all of which reduces uncertainty and imprecision (Munda and Nardo, 2005a). The main drawback to this method is that the number of permutation calculations rises exponentially as the number of countries increases (Munda, 2005). This, however, is not a serious issue given the capabilities of personal computers.

The Condorcet technique is detailed below.

An Axiomatic Setting of the Condorcet Method

When evaluating countries against each other, one finds that some variables favour one country while other variables favour another. Overcoming these inconsistencies on the perceived impact of variables in a non-compensatory manner will enable progress measures to appropriately rank different countries. When rankings are based on ordinal information, which is invariably the case in all situations, the only alternative is the Condorcet approach (Arrow and Raynaud, 1986).[3] However, one drawback to this approach is the algorithm's inherent problem with the presence of cycles.

Specifically, the probability $\pi(N,M)$ of obtaining a cycle with N countries and M individual indicators rises with N as well as the number of indicators. Given that cycles can occur quite regularly with macroeconomic data, the relevant process should be capable of handling this issue. This problem, in fact, was recognised by Condorcet himself (Munda, 2005).[4]

Although Kemeny (1959) worked mostly on clarifying this, it was Young and Levenglick (1978) who provided a complete axiomatic approach to solve the problem. Hence the approach is known as the Condorcet-Kemeny-Young-Levenglick (CKYL) ranking procedure. Arrow and Raynaud (1986) abandon the Kemeny method due to its tendency to produce preference reversal. According to Munda (2005) and Munda and Nardo (2005a), the most appropriate approach to deal with cycles is to employ the CKYL ranking procedure, all the while accepting that rank reversals may occur.

It is suggested that rank reversal is not consistent with Arrow's axiom of independence of irrelevant alternatives. More importantly, as Young (1988) asserts, the CKYL procedure is the only conceivable ranking procedure that is locally stable, which helps to preserve the ranking of alternatives when only an interval of the full ranking is measured. Besides, adapting the CKYL ranking procedure for a CI is straightforward (Munda, 2005).

The maximum likelihood ranking of countries is the ranking supported by the maximum number of individual indicators for each pair-wise comparison, summed over

[3] The Condorcet method is based on his work in 1785 titled, *Essai sur l'application de l'analyse a la probabilite des decisions rendues a la probabilitie des voix*. This citation appears in the reference section of Munda (2005) and Munda and Nardo (2005a).

[4] The formulas and summary are derived from Munda (2005, pp. 962-964) and Munda and Nardo (2005a, pp. 6-7).

all pairs of countries involved. A simple, yet formal, ranking algorithm derived on these concepts follows.

Given a set of individual indicators $G = \{g_m\}, m = 1,2,...,M,$ and a finite set $A = \{a_n\}, n = 1,2,...,N$ of countries, let's assume that the evaluation of each country a_n with respect to an individual indicator g_m (i.e., the indicator score or variable) is based on an *ordinal, interval* or *ratio* scale of measurement. A higher value of an individual indicator is preferred to a lower one (the higher, the better), that is:

$$\begin{cases} a_j P a_k \Leftrightarrow g_m(a_j) > g_m(a_k) \\ a_j I a_k \Leftrightarrow g_m(a_j) = g_m(a_k) \end{cases} \tag{1}$$

where P and I indicate a preference and an indifference relation respectively, both satisfying the transitive property.

Another assumption is made regarding the existence of a set of individual indicator weights $W = \{w_m\}, m = 1,2...,M,$ with $\sum_{m=1}^{M} w_m = 1,$ derived as importance coefficients. Mathematically, the problem is how to rank in a complete pre-order (i.e., without any incomparability relation) the selected countries from best to worst given the information available. This can best be achieved by a mathematical aggregation convention which is divided into two steps:

i) pair-wise comparison of countries according to the whole set of individual indicators used; and

ii) ranking of countries in a complete pre-order.

A pair-wise comparison of countries requires the following axiomatic system, which is adapted from Arrow and Raynaud (1986, pp. 81-82).

Axiom 1: Diversity

Each individual indicator is a total order on the finite set *A* of countries to be ranked, and there is no restriction on these indicators; they can be any total order on *A*.[5]

[5] In the original, Arrow and Raynaud (1986) talk about a finite set X of alternatives, with no restriction condition on the criteria that can be any total order on X.

Axiom 2: Symmetry

The individual indicators possess non-comparable scales, therefore the only information they provide is the ordinal pair-wise preferences they contain. This is an essential axiom given that intensity of preferences and compensability are bypassed and that weights need to be symmetrical importance coefficients. Furthermore, this axiom helps reduce uncertainty and imprecision since a normalisation step is not required.

Axiom 3: Positive Responsiveness

The degree of preference between two countries *a* and *b* is a strictly increasing function of the number and weights of individual indicators that rank *a* before *b*.[6] According to Munda (2005) and Munda and Nardo (2005a), in social choice terms the equal treatment of all individual indicators (anonymity) is broken. Thus, according to Arrow's impossibility theorem a trade-off occurs between decisiveness where a ranking or alternative has to be chosen, and anonymity. In such instances, decisiveness is preferred.[7]

The three axioms therefore, allow a $N \times N$ matrix E, called an *outranking matrix* to be constructed which supposes that all available information is contained within (Arrow and Raynaud, 1986; Roy, 1996). Any generic element of $E : e_{jk}, j \neq k$ is the result of the pair-wise comparison, according to all the M individual indicators, between countries j and k. The following equation facilitates the attainment of a global pair-wise comparison:

$$e_{jk} = \sum_{m=1}^{M} \left(w_m \left(P_{jk} \right) + \frac{1}{2} w_m \left(I_{jk} \right) \right) \qquad (2)$$

where $w_m(P_{jk})$ and $w_m(I_{jk})$ are the weights of individual indicators representing a preference and an indifference relation respectively. It clearly holds that:

$$e_{jk} + e_{kj} = 1 \qquad (3)$$

All the $N(N-1)$ pair-wise comparisons compose the outranking matrix E. Call R the set

[6] Once again, in the original, Arrow and Raynaud (1986) talk about the intensity of preferences between two alternatives x_i and x_j.

[7] Furthermore, as Munda (2005) states, it is essential that no individual indicator weighs more than 50 per cent of the total weight; otherwise the aggregation procedure would become lexicographic in nature, and the indicator would become a dictator in Arrow's term.

of all $N!$ possible complete rankings of alternatives, $R = \{r_s\}, s = 1,2,...,N!$. For each r_s compute the corresponding score φ_s as the summation of e_{jk} over all the $\binom{N}{2}$ pairs j,k of alternatives, i.e., $\varphi_s = \sum e_{jk}$, where $j \neq k, s = 1,2,...N!$ and $e_{jk} \in r_s$.

The final ranking $(r*)$ is the one that maximises the equation below, which is:

$$r* \Leftrightarrow \varphi_* = \max \sum e_{jk} \text{ where } e_{jk} \in R. \tag{4}$$

Of course these are not the only formal properties of the CKYL, others are (Young and Levenglick, 1978; Munda, 2005):

- *Neutrality:* all countries are treated equally.
- *Unanimity:* if country *a* is preferred to country *b* by all the individual indicators than *b* should not be chosen (sometimes called Pareto optimality).
- *Monotonicity:* if country *a* is preferred in any pair-wise comparison and *only their* individual indicator scores (i.e., the variables) are improved, then *a* should continue to be the winning country.
- *Reinforcement:* if the set *A* of countries is ranked by two subsets G_1 and G_2 of the individual indicator set *G*, such that the ranking is the same for both G_1 and G_2, then $G_1 \cup G_2 = G$ should still supply the same ranking. This general consistency requirement is very important for a progress framework, since it can be applied to individual indicators belonging to each single dimension of progress prior to pooling them in the general model.

Given the importance of the reinforcement property stated above, the maximum likelihood ranking procedure is the only Condorcet consistent rule that holds the reinforcement property. As Arrow and Raynaud (1986) state, this property is highly relevant to welfare economics and political science due to its definite ethical content.

In any aggregation technique, practical compromises need to take place. For instance, under a Condorcet approach anonymity is lost as is the information on the intensity of preferences of the variables. The latter however can be made up by complementing the Condorcet approach with a benchmarking approach to form as a comparison with the Condorcet only approach. These practical compromises are a necessary price to ensure that compensability is reduced and that weights can be considered as symmetrical importance coefficients (Munda and Nardo, 2005a).

The employment of the Condorcet approach enables researchers to reduce one of the main sources of uncertainty and imprecision (Munda and Nardo, 2005a). To help further reduce this, a sensitivity analysis should also be performed since it increases the defensibility of the chosen method.

3 Theoretical Implications of the Condorcet Method

A major advantage of employing the Condorcet method for aggregating progress measures lies in the methodology. As the present paper has demonstrated, under a Condorcet aggregation weights are never combined with intensity of preferences. This preserves the theoretical importance of the coefficients which means that the degree of compensability is at a minimum.

This has important implications for progress measures and policymakers since measures of progress serve as a crucial link between the economy and the nation's policymaking establishment. Given that the idea of efficient allocation of resources is such a powerful influence in economics, a progress measure can serve as a basis for decisions to improve resource allocation. Such decisions therefore need to be made in the absence of any trade-offs between areas within a progress measurement.

For example, the HDI aggregation technique embraces compensability. Hence, a strong performance in one dimension (say GDP) can overcome poor outcomes in either the health or education dimensions (see: McGillivray and White, 1993; Dijkstra and Hanmer, 2000; Cahill 2005). An important implication of this property of compensability is that underperforming areas of the economy will be masked by the stronger ones resulting in sub-optimal allocation of resources from misguided policies. The Condorcet's ability to find compromises between two or more legitimate goals not only assures non-compensability but, more importantly from a policymaking perspective, it also ensures that one strongly performing dimension cannot compensate for poorly performing dimension(s).

It is this principle (the non-balancing effect of this aggregation technique) which carries with it important implications from a policy viewpoint. It has the ability to detect underlying 'weak' dimensions while also facilitating the employment of potential policy prescriptions to overcome these shortcomings.

As mentioned in section 2.3, since weights are never combined with intensity of preferences, the Condorcet approach, unlike the more established distance to leader approach, should have a minimum possible level of degree of compensability with the aggregation model. Consequently, an empirical application of the Condorcet method is undertaken on the resource-infrastructure-environment (RIE) index and compared to the distance to leader approach to test the extent to which the Condorcet results differ.

4 Testing the Condorcet Approach

The structure of the RIE progress measure incorporates three main areas (resources, infrastructure, and environment) and breaks these into themes and dimensions. In all, there are seven themes and 23 dimensions.[8] Table 1 below lists the areas, themes and dimensions of the RIE index.

Insert Table 1 here

The RIE index analysed three countries (Australia, Mexico, and the US) over a 15 year time-period (1990-2004) using the Condorcet aggregation approach. In keeping with Munda (2005), a confirmation of the significant improvement in problem modelling arising from the Condorcet aggregation approach should enable it to produce fairly similar results to distance to leader method.

The distance to leader approach is used by the HDI to aggregate their results. Traditionally, the weighting is realised by dividing the sub-indicator values by the corresponding target values, both expressed in the same units. The CI is then computed as a simple average of these dimensionless parameters. It has also been used to examine the gap between nations and an 'ideal' performance level. For the purposes of this study, the best performing country in each of the 23 dimensions was designated as the respective dimension leader. Table 2 below shows the trend results obtained from conducting a comparison between the two approaches.

Insert Table 2 here

Over the 15-year period the results are alike except for two periods (1992 and 1997) where the Condorcet produces a MAU ordering. This slight variation should reflect changes in certain variables. Importantly for this paper, the similarity of the results suggests that there is not anything evidently unacceptable with the applied Condorcet aggregation approach.

[8] The RIE index was developed by Natoli (2008). Natoli and Zuhair (2010) provide a detailed explanation of the RIE.

5 Conclusion

This paper revised the three main aggregation techniques employed for progress measures, with the advantages of the Condorcet approach highlighted. Specifically, the Condorcet method was shown to reduce the main source of uncertainty and imprecision when aggregating progress measures. It also preserved the theoretical importance of the coefficients, which meant that the degree of compensability is at a minimum. This reduction in uncertainty strengthens the validity and defensibility of any measure which adopts this technique.

As expected, the empirical application demonstrated that the Condorcet method produced similar results to the more established distance to leader approach. This similarity meant that the applied Condorcet aggregation approach is acceptable. Additionally, the slight variation suggests that the Condorcet's utilisation of a minimum degree of compensability level was able to pick up on changes in variables that would otherwise have gone unnoticed. This is important given that progress measures can serve as a basis for decisions to improve resource allocation.

REFERENCES

Anderson, N. H and J. Zalinski (1988) “Functional Measurement Approach to Self-Estimation in Multiattribute Evaluation”, *Journal of Behavioral Decision Making*, 1(4), pp. 191–221.

Arrow, K. J and H. Raynaud (1986) *Social Choice and Multicriterion Decision-making* (Cambridge: MIT Press).

Bohringer, C and P. Jochem (2007) “Measuring the Immeasurable: A Survey of Sustainability Indices”, *Ecological Economics*, 63(1), pp. 1–8.

Bouyossou, D. (1986) “Some Remarks on the Notion of Compensation in MCDM”, *European Journal of Operational Research*, 26(1), pp. 150–160.

Cahill, M. (2005) “Is the Human Development Index Redundant?” *Eastern Economic Journal*, 31(1), pp. 1–5.

Condorcet, Marquis de. (1785) *Essai Sur L’application de L’analyse a la Probabilite des Decisions Rendues a la Probabilitie des Voix* (Paris: De L’ imprimerie Royale).

Desai, M. (1991) “Human Development, Concepts and Measurement”, *European Economic Review*, 35, pp. 350–357.

Dijkstra, G. A and L. Hanmer (2000) “Measuring Socio-Economics Gender Inequality: Towards an Alternative to the UNDP Gender-Related Development Index”, *Feminist Economics*, 6(2), pp. 41–75.

Ebert, U and H. Welsch (2004) “Meaningful Environmental Indices: A Social Choice Approach”, *Journal of Environmental Economics and Management*, 47(2), pp. 270–283.

Funtowicz, S. O., G. Munda and M. Paruccini (1990) “The Aggregation of Environmental Data Using Multicriteria Methods”, *Environmetrics*, 1(4), pp. 353–368.

Gasparatos, A., M. El-Haram and M. Horner (2008) “A Critical Review of Reductionist Approaches for Assessing the Progress Towards Sustainability”, *Environmental Impact Assessment Review*, 38(4-5), pp. 286–311.

Kemeny, J. (1959) “Mathematics Without Numbers”, *Daedalus*, 88, pp. 571–591.

McGillivray, M and H. White (1993) “Measuring Development? The UNDP’s Human Development Index”, *Journal of International Development*, 5(2), pp. 183–192.

Moulin, H. (1988) *Axioms of Cooperative Decision-Making* (Cambridge: Cambridge University Press).

Munda, G and M. Nardo (2005a) “Non-compensatory Composite Indicators for Ranking Countries: A Defensible Setting”, *EUR Report*, EUR 21833 EN (Ispra: European Commission Joint Research Centre).

Munda, G and M. Nardo (2005b) “Constructing Consistent Composite Indicators: The Issue of Weights”, *EUR Report*, EUR 21834 EN (Ispra: European Commission Joint Research Centre).

Munda, G. (1995) *Multicriteria Evaluation in a Fuzzy Environment: Theory and Applications in Ecological Economics*, Heidelberg: Physica-Verlag.

Munda, G. (2005) “Multiple Criteria Decision Analysis and Sustainable Development” in J. Figueira, S. Greco and M. Ehrgott (eds), *Multiple-Criteria Decision Analysis: State of the Art Surveys* (New York: Springer), pp. 953-986.

Nardo, M., M. Saisana., A. Saltelli., S. Tarantola., A. Hoffman and E. Giovannini (2005a) “Handbook on Constructing Composite Indicators: Methodology and User Guide”, *OECD Statistics Working Papers STD/DOC (2005) 3* (Paris: OECD).

Nardo, M., M. Saisana., A. Saltelli., S. Tarantola., A. Hoffman and E. Giovannini (2005b) “Tools for Composite Indicators Building”, *EUR Report*, EUR 21682 EN (Ispra: European Commission Joint Research Centre).

Natoli, R. (2008) *Indicators of Economic and Social Progress: An Assessment and an Alternative*. Unpublished Thesis, Victoria University, Australia.

Natoli, R and S, Zuhair (2010) “Establishing the RIE index: A review of the components critical to progress measurement”, *International Journal of Social Economics*, 37(8), pp. 574–591.

Podinovskii, V. V. (1994) “Criteria Importance Theory”, *Mathematical Social Sciences*, 27(3), pp. 237–252.

Roy, B. (1996) *Multicriteria Methodology for Decision Aiding* (Boston: Kluwer Academic Publishers).

Sagar, A. D and A. Najam (1998) “The Human Development Index: A Critical Review”, *Ecological Economics*, 25(3), pp. 249–264.

Young, H. P and A. Levenglick (1978) “A Consistent Extension of Condorcet’s Election Principle”, *SIAM Journal of Applied Mathematics*, 35(2), pp. 285–300.

Young, H. P. (1988) “Condorcet’s Theory of Voting”, *American Political Science Review*, 82(4), pp. 1231–1244.

TABLE 1

COMPONENTS OF THE RIE FRAMEWORK

Area	**Theme**	**Dimension**
Resources	**Human**	Health
		Population
		Food Consumption
		Education & Training
		Knowledge Renewal
		Net Brain Gain
	Natural	Land & Agricultural Use
		Energy Production and Use
		Water
		Fisheries
		Biodiversity
	Generated	Financial
		Physical Capital
Infrastructure	**Information & Communications Technology (ICT)**	ICT Access
	Transportation	Transportation Efficiency
Environment	**Physical**	Air Quality
		Greenhouse Gas Emissions
		Conspicuous Consumption
		Built Environment
		Access to Essential Services
	Socio-cultural	Social Connectedness
		Institutional Quality
		Economic Security

TABLE 2

COMPARING THE CONDORCET WITH THE DISTANCE TO LEADER APPROACH

	1990	1992	1995	1997	2000	2004
Condorcet	AMU	MAU	AMU	MAU	AMU	AMU
Distance to Leader	AMU	AMU	AMU	AMU	AMU	AMU

Note: A = Australia, M = Mexico and U = United States.