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Contents

Open issues in composite indicators construction

Problematiche aperte nella costruzione di indicatori compositi

Leonardo Salvatore Alaimo

Abstract Composite indicators are useful to represent in a easy-to-read way a complex phenomenon. Over the years, their use has significantly, both among academics and policy makers. At the same time, issues related to their use have emerged. They constitute open questions in the debate on the subject and frontiers for the research. In this paper, we aim to briefly present the state of the art on this topic and illustrate the main issues and the directions the literature has taken to address them. The latter constitute potential topics of interest also for those who want to undertake the study of composite indicators for the first time.

Abstract *Gli indicatori compositi sono utili per rappresentare in modo semplice e immediatamente comprensibile un fenomeno complesso. Nel corso degli anni, il loro uso è aumentato significativamente, sia tra gli accademici che tra i decisori pubblici. Allo stesso tempo, sono emerse questioni relative al loro uso, che costituiscono argomenti aperti nel dibattito e nuove frontiere per la ricerca. In questo articolo, ci proponiamo di presentare brevemente lo stato dell'arte su questo tema e di illustrare le questioni principali e le direzioni che la letteratura ha preso per affrontarle. Queste ultime costituiscono potenziali argomenti di interesse anche per chi voglia intraprendere per la prima volta lo studio degli indicatori compositi.*

Key words: Multi-indicators systems, Synthesis of statistical indicators, Composite indicators

1 Introduction

As Karl Pearson stated *if you haven't measured something, you really don't know very much about it*. Measurement allows the production of scientific knowledge

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about reality. Indeed, it develops as a *dialogue between logic and evidence*, it is the result of a complex interaction between theory and observations represented and realized by measurement. This interaction is necessary and unavoidable [1]. Dealing with phenomena defining reality (wellbeing, poverty, quality of life, development, and so on) requires an approach capable of grasping their complex and multidimensional nature. They are *complex adaptive systems*, i.e. open systems made up of numerous elements interacting with each other, in a linear and a non-linear way, that constitute a unique and organic entity capable of evolving and adapting to the environment [2, 3, 4]. They are multidimensional and their different elements are linked together in a non-linear way. They evolve over time, modifying both their dimensions and the links between them. Consequently, their measurement needs to consider different aspects. They are not directly observable, but they derive theoretically from observations. Almost all measures in social sciences are developed by means of a *defining process*, namely achieved as a consequence of a definition confirmed through the relationship observed between observations and the concept to be measured. The measurement process in social sciences is associated with the construction of systems of indicators. It is necessary to use a variety of elementary indicators and a criterion for summarising the information they contain. In statistics, an elementary indicator refers to indirect measures of phenomena that cannot be measured directly. In this perspective, an indicator is not simply raw statistical information, but represents a measure organically linked to a conceptual model aimed at describing different aspects of reality. They are not simply collections of measures. Indicators within a system are interconnected and new properties typical of the system and not of its constituent elements emerge from these interconnections. Therefore, a system of indicators allows the measurement of a complex concept that would not otherwise be measurable by taking into account the indicators individually. They play a key role in describing and understanding socio-economic phenomena. The complex nature of systems of indicators requires approaches allowing more concise views in order to analyse and understand them. The guiding concept is *synthesis*. The synthesis of indicators' systems has become a main issue in the literature. A variety of statistical methods useful for this purpose have been defined and used. From a technical perspective, these methods can be classified into two different approaches: the aggregative-compensative [5] and the non-aggregative [6, 7, 8, 9]. In this paper, we focus on the first one, the dominant framework in literature. Despite its success, the aggregative-compensative approach has been criticised and a series of conceptual and methodological issues have been posed. These questions are still open and inflame the debate in the literature on this topic. In this paper, we focus on some of them and how they constitute frontiers for the research in the composite indicators' field. Why should we continue to work and research on composite indices? We will try to answer this question.

2 Composite indicators: some conceptual and methodological research questions

A system of indicators is a three-way data array of type "same objects × same indicators × time occasions", which can be algebraically formalised as [10]:

$$\mathbf{X} \equiv \{x_{ijt} : i = 1,\ldots,N;\ j = 1,\ldots,J;\ t = 1,\ldots,T\} \tag{1}$$

where the indices i, j and t stand for the units, the indicators and the times, respectively and x_{ijt} is the value of the j-th indicator observed for the i-th unit at time t. These data structures are characterised by a great complexity and require the use of specific statistical tools allowing a more concise view. Given $\mathbf{X} \equiv \{x_{ijt}\}$, the objective of the synthesis, generally, is to obtain a bi-dimensional data matrix:

$$\mathbf{V} \equiv \left\{v_{it} : i = 1,\ldots,N; t = 1,\ldots,T\right\} = \begin{pmatrix} v_{11} & v_{12} & \cdots & v_{1T} \\ v_{21} & v_{22} & \cdots & v_{2T} \\ \vdots & \ddots & \ddots & \vdots \\ v_{N1} & v_{N2} & \cdots & v_{NT} \end{pmatrix} \tag{2}$$

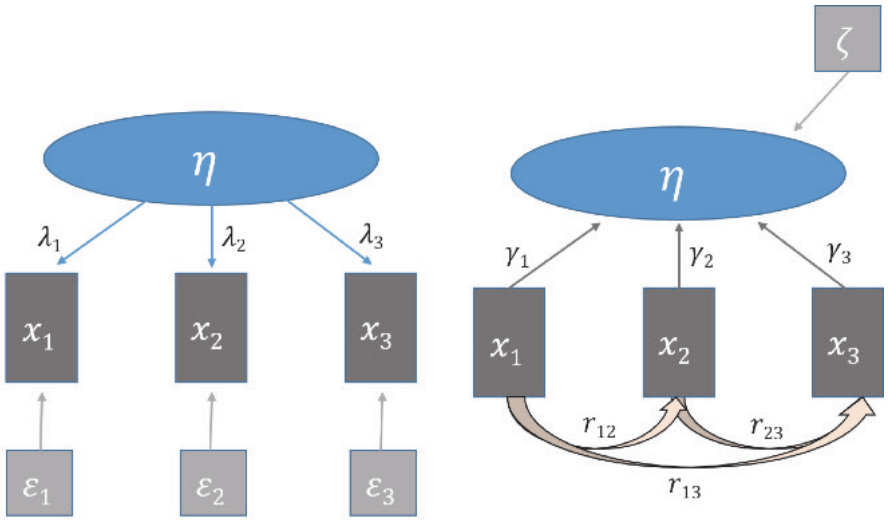
where v_{it} is the synthetic value of the unit ith at the time t-th. In the aggregative-compensative approach, the synthesis of $\mathbf{X}$ is performed by means of a mathematical function that combines the (previously normalised) basic indicators. In other words, it consists of the mathematical combination (or aggregation) of the set of indicators, obtained by applying specific methodologies [11] known as composite indicators (CIs). Over the years, these methodologies have been widely used in literature and by various international organisations and institutions for measuring and evaluating a great variety of socio-economic phenomena. The main purpose of their importance and success is to be informative. It is easier for the public to understand a synthetic indicator (one single measure) than many elementary indicators.

One of the main critical points is the treatment of multidimensional systems of ordinal data [7]. Ordinal indicators cannot be synthesised by using an aggregative method, suitable only for cardinal data. In fact, ordinal scores cannot be treated as numbers. Despite this, we often see their transformation into numerical scores, by more or less sophisticated scaling tools, in order to make possible their synthesis by aggregative procedures. These procedures may lead to controversial and incorrect results and pose delicate methodological and conceptual questions. This has led researchers to identify methods that can deal with non-cardinal indicator systems.

Another focal issue in composites construction is how to treat subjectivity. It is involved in any phase of composites' construction. Subjectivity is not negative per se, but it becomes so when it turns into *arbitrariness*. The first step in any synthesis is the definition of the phenomenon we want to measure and the subsequent identification of the theoretical framework and the relevant variables. The concept must always refer to a theoretical framework that gives it meaning. No meaning can be attributed without subjectivity. The role of the subject in knowledge production is clear. Fundamental attention must be given to the analysis of the *measurement*

model, referring to the relationship between concepts and indicators. The debate on measurement models is part of the literature on the evaluation of latent variables, which has a long tradition in social science [12]. Latent variables are phenomena of theoretical interest which cannot be directly observed and have to be assessed by manifest measures which are observable. Two different conceptual approaches can be identified: *reflective* and *formative* [13, 14, 15, 16, 17].

Fig. 1: Measurement models: reflective (left); formative (right).



The reflective measurement models have a long tradition in social sciences (in particular, in psychometric research) and are based on classical test theory, according to which measures are effects of an underlying latent construct [18]. Therefore, causality is from the construct to the measures and, consequently, a change in the latent variable causes variation in all measures simultaneously (all indicators must be positively correlated). In a formative model, indicators are causes of the construct rather than its effects (like in the reflective one) and they determine the latent variable giving it its meaning [13, 19]. Accordingly, indicators are not interchangeable: omitting an indicator is omitting part of the construct [20]. Thus, the choice of indicators determines what we want to measure.

The literature about the difference between reflective and formative models is rich and the debate on this issue continues. We would like to point out that the choice between the two models does not depend on the researcher, but exclusively on the nature and direction of relationships between constructs and measures. Different methods of normalisation, weighting and aggregation exist and can be used, leading to different results and interpretations. Of course, the choice of methods is also subjective, although it must be guided by knowledge of the phenomenon and

based on clear assumptions so as not to be arbitrary. Each method has strengths and weaknesses. Different choices lead to different syntheses that often give a different interpretation of the phenomena studied. These considerations lead to two research questions. The first is whether, given a system of indicators, there can be a method that is better than the others, i.e. that is able to represent the phenomenon better than the others. The second question, strictly linked to the previous one, is whether it is possible to define a criterion for choosing such a method.

As highlighted in equation 2, the synthesis aims at obtaining for each unit of the original system a synthetic measure that is representative of its original profile (i.e., the combination in the basic indicators) at a specific time t-th. Such a measure gives an easy-to-read information about the phenomenon. Switching from multi-dimensional to uni-dimensional necessarily determines a loss of information, justified by the need to have a synthetic view of the measured phenomenon. In many cases, this loss of information is excessive. Synthesising a complex phenomenon into a single number can be not straightforward and lead to misleading results and conclusions which increase if the indicator is poorly defined and constructed. This can lead researchers and/or policy-makers to give an over-simplistic interpretation of a phenomenon. This aspect has been investigated in literature and has prompted researchers to question whether the synthesis of a multi-indicators system must necessarily be a single number assigned to each statistical unit at a specific time.

3 Frontiers of the research

The questions presented in the previous section constitute challenges for researchers and the answer to them might be a reason to approach the study of composite indicators.

The impossibility of synthesising indicator systems in which non-cardinal indicators are also present is intrinsically linked to the nature of composite indicators, which are obtained through the mathematical combination of elementary indicators. For this reason, over the years the research has focused on finding methods suitable for dealing with systems of indicators at different scaling levels. In this way, the so-called non-aggregative approach gradually became widespread: the synthetic indicator is obtained without any aggregation of the basic indicators. Among the different methodologies belonging to this approach (for instance, the Social choices theory [21, 22, 23] or the Multi-criteria Analysis [24, 25, 26]), the Partially Ordered Set (poset) Theory [27, 28, 29] has become a reference. The spread of these new methods was facilitated by the concomitant spread of increasingly powerful computer tools, which made their computation possible. Undoubtedly, research is moving towards the identification of methods that do not depend on and can, consequently, be used regardless of the scale of the elementary indicators. Subjectivity is an ineradicable element, but it must never become arbitrariness. Research has also focused on the management of the various subjective choices involved in the composites' construction. As regards the definition of the phenomenon to be measured

and the choice of the elementary indicators, one way to avoid arbitrariness is to stand *on the shoulders of giants* [30], i.e. always rely on a careful analysis of the literature and what others have done before. This does not translate into a kind of immobility, into the impossibility of departing from what has been done in the past. On the contrary, research in the field of indicators is highly dynamic as it is linked to societal evolution. For instance, if we wanted to construct an indicator measuring deprivation, we could not disregard the work on this subject by Townsend [31]. It is clear that the deprivation nowadays is not the same as it was in Townsend's reference and that the concept must therefore be adjusted. However, Townsend's work would be the starting point. Research in the field of indicators' synthesis is alive and evolving; phenomena change in different contexts (spatial, temporal, cultural). In this perspective, the researcher plays a decisive role and subjectivity becomes the lens through which he or she observes the world in an unique way. As mentioned above, the methodological choices are also subjective (obviously, based on the knowledge of the phenomenon) and different methods lead to different results. The research therefore focused on identifying *the best method* for the synthesis. There is no absolute method that is preferable to all others. However, a criterion for choosing a method would be useful. We often deal with CIs obtained by the most different methods, often chosen arbitrarily by the researchers. This makes the choices questionable. But, even if the choices are agreeable, it remains to be seen how much a method is a "good and valid choice". In this perspective, different authors [32, 33] have suggested robustness as a selection criterion: among the different choices and methods, we must select those which guarantee greater robustness of rankings, assessed by means of uncertainty analysis (how uncertainty in the input factors propagates through the structure of the composite index and affects the results) and sensitivity analysis (how much each individual source of uncertainty contributes to the output variance). However, this approach leaves a question open: why should a more robust method better represent a phenomenon? In particular, the idea that preferring the method which, by excluding and including individual indicators and setting different decision rules to construct the composite index, leaves the rankings obtained most unchanged is highly questionable. It could be argued that such an approach does not take the measurement model into account. Indeed, in a reflective model, the exclusion of an indicator does not affect the latent variable that is being measured. On the contrary, in a formative model excluding or including an indicator changes, even strongly, the measured latent variable. Let's take an example. Suppose we want to measure human development using UNDP's framework [34], considering three dimensions and four indicators: a long and healthy life assessed by life expectancy at birth; knowledge measured by means of mean years of schooling for adults aged 25 years and more and expected years of schooling for children of school entering age; a decent standard of living measured by gross national income per capita. If we remove the economic variable, we expect a significant change in the ranking obtained which will be different from that obtained by excluding life expectancy. Consequently, why, among the various methods, should we choose the one that leaves the rankings obtained by excluding an indicator more unchanged? As easily understood, the debate on this issue is very lively. Recently, an approach

linking the choice of method to the nature and structure of the indicators' system has been proposed. It is quite obvious that a good synthetic measure should give a good fit of the distributive assumptions on data. In other words, a composite can be considered "good" if it is able to give a good representation of the distributional form (or multiple forms) assumed on the system of indicators.

The last question addressed in this work is if the synthesis must necessarily be a single number or, more precisely, whether a single number is capable of accounting for the complexity of the observed phenomenon. In literature, we can find arguments in favour of the composites and against them. Some scholars [35] criticised the choice of constructing a single composite index, suggesting that it would be a better choice to use a dashboard, because it allows to avoid an arbitrary choice of the functional form and the weighting scheme and to observe a phenomenon from multiple points of view. In this perspective, the synthesis is an informative patrimony capable of describing the observed reality. Other researchers highlighted that a synthetic measure can be an object, a map or an image. There is a large amount of literature on the use of metaphoric images for the representation and synthesis of socio-economic phenomena [36, 37]. Another approach is to use intervals of composites rather than individual measures [38, 39, 40, 41]. The proposed intervals, although different one another, all respond to the idea of identifying a range of values within which the synthetic measure is included.

4 Conclusions

Composites indicators are a tool for measuring and understanding phenomena. They have become the focus of attention of researchers and policy makers for their ease of reading and usefulness for decision making and evaluation. Over the years, their use has increased, as well as the areas in which they have been applied. At the same time, the debate in the literature has become increasingly animated, focusing on problems and new areas of application and frontiers of research. In this paper, we have presented some of them, which are, of course, only examples that, although relevant, do not do justice to the enormous academic debate and production on composite indicator topic. This testifies to the liveliness of research in this field, the possibility of exploring new or established themes from new perspectives. Undoubtedly, we can consider this an adequate answer to why we must continue to study composite indicators.

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