A new hierarchical model-based composite indicator on climate change

Un nuovo indicatore composito basato su un modello gerarchico per il cambiamento climatico

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1 Introduction

Nowadays climate change is a crucial and compelling topic in public debate because of the risks for human life it could entail. The current warming trend is particularly significant and the entire scientific community warns governments to take action to reduce detrimental effects of the human activity.

Although climate on Earth has changed throughout history, the growing attention on it is due to the unprecedented speed at which it is changing and the huge impact it could have on Earth's life. It depends on different causes and it will affect several aspects of the environment. This is the reason why a global counter-action is essential.

The main cause of the global climate change is the increase of the the greenhouse effect, i.e. greenhouse gas emissions from human activities, which blocks heat from being emitted in the atmosphere. The concentration of gas emissions such as water vapour, carbon dioxide (CO_2), methane (etc.) has increased with respect to the combustion of fuels to fulfil a growing request of energy.

The impacts of climate change may be directly detected into evident environmental changes such as the rising of global temperatures, the changes in precipitation patterns, the recurring droughts, the heat waves and extreme events, the increasing of the sea level, the melting glaciers; all events which have already been observed in our planet in the last years.

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Therefore, it is necessary to provide policy-makers with the right tools to inspect this complex phenomenon and to address policies for fighting climate drift. Some efforts are now put into practice through international initiatives in the sustainable development field, as the identification of a set of indicators to define climate action (Sustainable Development Goals, SGD 13), or the international cooperation to implement the commitment of the Paris Agreement, which involves 174 countries and the European Union as a whole.

In this paper, a composite indicator on climate change is proposed by using a hierarchical model-based approach. Composite indicators (CIs) are useful tools to measure multidimensional concepts and to represent them by means of a unique measure of synthesis, which stands for a relevant benchmark in policy-making. Since several aspects define climate change, the latter may be considered as a latent multidimensional phenomenon with different underlying observable effects.

The paper is organised as follows. Section 2 briefly describes the methodology used for the construction of the climate change composite indicator, whose results are analysed in depth in Section 3.

2 Methodology

Composite indicators are generally used to summarise complex realities into a unique measure, which could be easier to interpret and useful to guide policy-makers decisions. Indeed, single observable manifest variables (MVs) are not able to represent a multidimensional phenomenon in all its aspects. [3] provides a technical guideline to build a CI, with the aim of improving their quality and having methodological common principles for their construction.

In many cases, the theoretical framework underlying complex phenomena is fundamental to define its measure of synthesis in a confirmatory approach, i.e. when the underlying theoretical model which defines the latent dimensions' relationships is known. However, unknown constructs could be hidden behind the complexity of the reality and they cannot be discovered lumping together all the MVs. Thus, inspecting different levels of syntheses could be crucial to understand the whole phenomenon under study. Nevertheless, CIs are built directly from a set of underlying manifest variables via their mean, with a simultaneous aggregation approach. As such, it is not feasible to define broader concepts derived from step-by-step aggregations of the MVs and to take into account the whole process to define a CI - which is necessary for its interpretation.

[1] proposed a new hierarchical model-based approach to build a composite indicator defining a bottom-up hierarchy. Its lowest level is composed by a reduced number of latent dimensions that are obtained with a dimensionality reduction technique. Each latent concept represents a subset of MVs, which allows to clearly define its meaning and interpretation. The successive hierarchical levels are developed lumping together pairs of variables groups to achieve a hierarchy, and each one can pinpoint a new broader dimension related to a larger group of MVs. This method-

ology allows to tackle the dimensionality reduction problem through a step-by-step approach for the CI construction and, thanks to the knowledge of the whole process, it allows to better understand the meaning of the provided measure of synthesis. Furthermore, it provides for a non-compensatory approach in the construction of the CI, searching for non-negative weights of the MVs.

3 Climate Change Composite Indicator

In the last decade, scientific evidence on climate change has been certainly unequivocal[1]. Its impacts have been tangible in everyday life and these can bring about negative consequences from an environmental, a social and an economic point of view. The international organisations such as United Nations or European Union have felt the necessity to take a lead in this topic. One of the first actions with the aim of improving countries' efforts to reduce gas emissions and to take under control the speed of climate change was done in September 2015, with the approval of the 2030 Agenda for Sustainable Development.

In fact, one of the 17 Sustainable Development Goals (SDGs, [2]) refers to Climate Action, focusing on climate mitigation, impacts and initiatives. A second relevant achievement on this topic was the Paris Agreement[2] adopted in December 2015, in which 174 countries and their respective governments have recognised climate change as an urgent problem to focus on.

Since the relevance of climate change on human life and the lack of a unique measure which takes into account all the possible facets of this broader phenomenon, we propose an extensive study on this topic and the corresponding construction of the climate change composite indicator according to the methodology described in Section 2.

Several aspects have to be considered because of the multidimensionality of the aforementioned phenomenon; indeed, climate change does not only depend on natural and astronomical causes but also, and mainly, on human activities. For these reasons, a comprehensive analysis of this phenomenon is necessary from the observable MVs, through the definition of latent underlying dimensions and up to a climate change composite indicator.

Among others, Eurostat has collected several indicators pertaining climate change which take into account all its possible effects, observable in Earth's planet. From the Eurostat's database, we have considered more than 40 manifest variables that are grouped into five main groups; each one is represented by a broader concept which contributes to our planet climate change. In particular, the main causes we have considered in the analysis concern greenhouse gas emissions, drivers (energy, transport,

[1] For some recommendations on climate change statistics: `http://www.unece.org/fileadmin/DAM/stats/publications/2014/CES_CC_Recommendations.pdf`.

[2] United Nations Paris Agreement (12 December 2015) can be found at the following link: `https://unfccc.int/sites/default/files/english_paris_agreement.pdf`.

industrial production, waste, land exploitation), mitigation in terms of environmental protection, impact and adaptation and climate action initiatives. All these latent dimensions represent a related set of underlying MVs which are collected for the 28 European Union Member States. The discarded variables have been chosen according to methodological requirements.

The methodology described in Section 2 has been applied to the selected data set to built a climate change composite indicator. One of its main advantage is that it allows to investigate the order and the magnitude of the hierarchical aggregations and, in several cases, it leads to the definition of new latent and not-theoretically defined dimensions. Furthermore, this methodology affords to compute a confirmatory or an exploratory analysis, in a theory-driven or data-driven approach, respectively. The objective of the latter case implemented in climate change context is to define unidimensional and reliable groups of MVs related to latent dimensions which are then merged in pairs to obtain a single measure of climate change. Analysing the results of the methodology described above, it is worthy to notice that the aim of investigating the bottom-up aggregations of the latent constructs is fulfilled.

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