Statistical polarization in greenhouse gas emissions: Theory and evidence*

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ABSTRACT

The current debate on climate change is over whether global warming can be limited in order to lessen its impacts. In this sense, evidence of a decrease in the statistical polarization in greenhouse gas (GHG) emissions could encourage countries to establish a stronger multilateral climate change agreement. Based on the interregional and intraregional components of the multivariate generalised entropy measures (Maasoumi, 1986), Gigliarano and Mosler (2009) proposed to study the statistical polarization concept from a multivariate view. In this paper, we apply this approach to study the evolution of such phenomenon in the global distribution of the main GHGs. The empirical analysis has been carried out for the time period 1990–2011, considering an endogenous grouping of countries (Aghevli and Mehran, 1981; Davies and Shorrocks, 1989). Most of the statistical polarization indices showed a slightly increasing pattern that was similar regardless of the number of groups considered. Finally, some policy implications are commented.

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1. Introduction

Climate change is one of the most important challenges facing the international community nowadays. Given its possible far-reaching consequences for ecosystems and the quality of life of hundreds of millions of people, climate change is a political issue on the global agenda as it was firmly established in the Third and Fourth Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC, 2001, 2007).

The principal causes of global warming are the anthropogenic emissions of greenhouse gases (GHGs), especially carbon dioxide (CO₂) from fossil fuel combustion. However, emissions of non-CO₂ GHGs, such as methane (CH₄), nitrous oxide (N₂O) and fluorinated gases (F-gases), also alter significantly the climate. A recent Greenhouse Gas Bulletin (World Meteorological Organization, 2016) shows that the concentration of CO₂, CH₄, N₂O has increased by 144, 256 and 121 percent since the year 1750, respectively. The increase in global CO₂ concentration is basically due to the fossil fuel combustion. CH₄ is emitted into the atmosphere from both natural (about 40 percent) and anthropogenic sources (approximately 60 percent). In the case of N₂O, close to 60 percent is emitted into the atmosphere by natural sources and about 60 percent comes from human activities. Although F-gases are still low in abundance, they are potent GHGs which are increasing at relatively rapid rates given its anthropogenic origin.

Given that non-CO₂ GHGs contribute more to global warming per unit mass than CO₂ (U.S. Environmental Protection Agency, 2012) and to reduce them is a relatively cheap complement to the cost associated to CO₂-only mitigation (U.S. Environmental Protection Agency, 2006), these gases have an important function in limiting global climate change. In addition, as these gases have much shorter lifetimes than CO₂, reducing their emissions offers an extra opportunity to curb climate change (Montzka et al., 2011; Weyant et al., 2006; Rao and Riahi, 2006).

In recent years the concept of statistical polarization has emerged to capture the inherent conflict or instability of a distribution. While inequality measures study the dispersion of a distribution with respect to a reference value, the statistical examination of polarization consists in identifying the appearance of poles in that distribution, which is related to multimodal distributions (Esteban and Ray, 1994; Wolfson, 1994). According to a
specific attribute, the notion of statistical polarization considers the population divided into different groups so that, the groups are internally homogeneous but different each other.

In the environmental field, global negotiations on reducing emissions are constructed through alliances of countries with conflicting interests. Thus, developed and developing countries have polarized positions given their different environmental responsibilities and level of development. Some experts have suggested that climate change will intensify resource scarcity, population displacements and fuel conflicts, being these effects particularly serious in developing countries where infrastructure is missing (Salehyan, 2008).

Given that climate change may cause conflicts between the haves and the have-nots, increasing even global inequality, international statistical polarization using only one gas has already been analysed in various studies. Thus, Ezcurra (2007) analysed the convergence in per capita CO₂ emissions using the EGR indices for the period 1960–1999. Meanwhile, Duro and Padilla (2008) used this same measure to investigate the same fact between 1971 and 2001. Duro (2010) examined the statistical polarization in per capita CO₂ emissions with exogenous groups based on the Z–K measure (Zhang and Kandur, 2001), whose main differential advantage lies in its factor-decomposability. Duro and Padilla (2013) analysed the degree of statistical polarization in the international distribution of per capita CO₂ emissions in the European Union, where the countries are grouped according to two criteria: their similarity in terms of emissions —endogenously— and their geographical location —exogenously. Finally, Duro and Teixidó-Figueras (2014) explored the distribution of per capita CO₂ emissions for the period 1992–2010 comparing different statistical polarization measures.

The principal limitation of the previous studies is that they only consider the distribution of CO₂ emissions, not giving a real picture of the international situation. In this sense, the extension of the preceding works to the analysis of the international distribution of the main GHG emissions is quite useful. On the one hand, it would give complete information about the possible political consequences of the emissions distribution, in terms of conflicts, and the probability of implementing international agreements. On the other hand, it would also give new insights of the Ecological Unequal Exchange framework.

Using the multivariate inequality measures proposed by Maasoumi (1986), and considering their decomposition into the between- and within-group inequality components, it is possible to obtain statistical polarization indices from a multivariate perspective (Gigliarano and Mosler, 2009). The main aim of this article is therefore to apply these indices to study the international statistical polarization in the distribution of the principal GHG emissions: CO₂, CH₄, N₂O and F-gases. Specifically, the empirical analysis is carried out for the time period 1990–2011 considering an endogenous grouping of countries (Aghelli and Mehran, 1981; Davies and Shorrock, 1989). Moreover, this paper is an extension of the results recently obtained by Remuzgo et al. (2016) on the study of the evolution of global inequality in GHG emissions from 1990 to 2011.

To the best of our knowledge, this is the first attempt to use multivariate statistical polarization measures for analysing, in a joint manner, the global distribution of GHG emissions. In this sense, the use of quantitative methods for analysing the historical trend of global statistical polarization in GHG emissions is a significant step towards solving the problem of climate change. Moreover, modelling the social effects of global warming will facilitate the dialogue on this issue between national governments, international organizations, non-profit groups and multinational firms in order to design effective global policies.

The rest of the paper is organised as follows. Section 2 examines the concept of statistical polarization, including the principal measures proposed in the literature. Next, the multivariate statistical polarization indices used in this paper are detailed. The main results of the analysis are exposed in sections 4 and 5. Finally, with the conclusions of the chapter, some policy implications are discussed.

2. The concept of statistical polarization

Inequality measures quantify the dispersion of a distribution with respect to a reference value —usually the arithmetic mean. However, to study some social phenomena is interesting to use a measure of the degree to which population is clustered around a number of poles at a certain distance. The concept of statistical polarization (hereinafter referred to as polarization) is directly related to the emergence of social tensions caused by a general dissatisfaction (Esteban and Ray, 1994; Wolfson, 1994). In statistical terms, the phenomenon of polarization leads to a distribution with more than one mode (Ezcurra et al., 2006).

The studies of polarization make possible to capture the potential conflict related to a given distribution. Thus, social tensions are more likely in a population distributed around two poles, that is, in a population divided into two groups of significant size with distinct characteristics. On the contrary, in a population with a high level of inequality, where a single individual has a characteristic opposite to that which is shared by the rest of the population, the development of social conflicts is not relevant. Polarization is enhanced when it is observed in the distribution a small number of groups of similar size, characterized by a high degree of internal homogeneity and heterogeneity among all of them.

In order to understand the concept of statistical polarization, the following example is considered. Suppose a population composed of six countries whose emissions levels are 2, 3, 4, 5, 6 and 7 tonnes, respectively. Next, assume that through transfers we have a two-point distribution concentrated equally on the emission levels 1 and 8. As illustrated in Fig. 1, the transfers of emissions lead to a distribution with only two levels of contamination: three countries pollute 1 tonne and the other three pollute 8 tonnes. Now, the society is divided into two distinct groups, that is, a polarized world

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1 The Ecological Unequal Exchange theory refers to the structurally determined disparity of natural resource consumption between the core and peripheral countries within the world-system (Hornborg, 2011) and its empirical analysis has become quite popular (see Teixidó-Figueras and Duro, 2014; Moran et al., 2013; Niccolucci et al., 2012; among others).

2 Using a different approach, Duro (2016) analysed the international distribution of GHG emissions both at global level and considering their three main sources —CO₂, CH₄ and N₂O— for the period 1990–2012.
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