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Evolution of the global inequality in greenhouse gases emissions using multidimensional generalized entropy measures

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HIGHLIGHTS

- We study the evolution of global inequality in GHGs emissions.
- We consider the four main greenhouse gases: CO_2, CH_4, N_2O and F-gases.
- We use multidimensional generalized entropy measures (Maasoumi, 1986).
- Inequality depends on the weight assigned to each part of the distribution.
- The variation of inequality is determined by the substitution degree among gases.

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ABSTRACT

Given the cumulative consequences of climate change, global concentration of greenhouse gases (GHGs) must be reduced; being inequality in per-capita emissions levels a problem to achieve a commitment by all countries. Thus, the evolution of carbon dioxide (CO_2) emissions inequality has received special attention because CO_2 is the most abundant GHG in the atmosphere. However, it is necessary to consider other gases to provide a real illustration of our starting point to achieve a multilateral agreement. In this paper, we study the evolution of global inequality in GHGs emissions during the period 1990–2011, considering the four main gases: CO_2, methane (CH_4), nitrous oxide (N_2O) and fluorinated gases (F-gases). The data used in this analysis is taken from the World Resources Institute (2014) and the groups of countries are constructed according to the quantity of emissions that each country released into the atmosphere in the first year of study. For this purpose we use the multidimensional generalized entropy measures proposed by Maasoumi (1986) that can be decomposable into the between- and within-group inequality components. The biggest fall in inequality is observed when we attach more weight to the emissions transfers between the most polluting countries and assume a low substitution degree among pollutants. Finally, some economic policy implications are commented.

1. Introduction

The increasing interest of physicists in complex economic and social systems has led to the emergence of the econophysics which is a new research field that applies the methods of statistical physics to problems in economics [1].

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These applications have provided important insights into income inequality,[1] wealth inequality and consumption inequality. In this sense, it should be highlighted the econophysical models applied to income and wealth distributions in the works of Chakrabarti et al. [5], Ghosh et al. [6] and Inoue et al. [7].

Climate change is undoubtedly the main environmental problem faced by humanity nowadays. The combustion of fossil fuels has released greenhouse gases (GHGs) emissions which had led to climate change threatening, at the same time, human health and settlement, ecological system, agriculture and water resources [8]. Thus, the aim of the celebration of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 was to limit global GHGs[2] emissions and stabilize their concentration in the atmosphere [10].

As carbon dioxide (CO_2) is the most abundant GHG in the atmosphere, the study of inequality in CO_2 emissions has received special attention by many authors. Among all the papers dedicated to analyze the evolution of the international inequality in CO_2 emissions, it is noted those carried out by Heil and Wodon [11,12], Hedenus and Azar [13], Sun [14], Alcántara and Duro [15], Padilla and Serrano [16], Ezcurra [17], Groot [18], Cantore and Padilla [19], Mahony [20], Remuzgo and Sarabia [21] and Lawrence et al. [22], among others.

However, human activity carried out during the industrial era has led to a dramatic increase of both CO_2 emissions and non-CO_2 GHGs emissions. In this sense, the non-CO_2 GHGs play an important role in understanding and curbing global climate change. The last *Greenhouse Gas Bulletin* [23] shows that the concentration of CO_2, methane (CH_4) and nitrous oxide (N_2O) has increased by 141, 260 and 120% since the year 1750, respectively. The increase in global CO_2 concentration is largely due to the use of fossil fuels, while the observed increment in the concentration of CH_4 and N_2O has its origin mainly in the agricultural practices [24]. Unlike the previous GHGs, fluorinated gases (F-gases) do not have natural sources and only come from human activities. The three main categories of F-gases are: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6). Despite the fact that the concentration of these gases is still low, they are the most potent and longest lasting type of greenhouse gases emitted by human activities [25].

Additionally, mitigating non-CO_2 GHGs can play an important role in global and regional climate strategy for two reasons. On the one hand, non-CO_2 GHGs contribute more to global warming per unit mass than CO_2 [26]. Thus, about 30% of anthropogenic greenhouse caused since preindustrial times can be attributed to them [27]. On the other hand, reduce non-CO_2 GHGs emissions is a relatively cheap complement to the cost associated to CO_2-only mitigation [28]. Therefore, the only consideration of CO_2 emissions cannot reflect the real situation of the current problem of climate change, being necessary to incorporate such gases in climate economic analyses.

The use of multidimensional measures allows us to study inequality in emissions of the four main GHGs emissions: CO_2, CH_4, N_2O and F-gases, also known as long-term gases. Methane damages the atmosphere about 28 times more than CO_2 over a 100-year period.[3]. The importance of this gas is due to its lifetime in the atmosphere — approximately 12 years[4] – which converts it into a key gas for curbing global warming because atmospheric concentrations of CH_4 could respond to mitigation actions in the short term. Nitrous oxide is about 265 times more potent than CO_2 at warming the atmosphere over a period of 100 years, having a long atmospheric lifetime — about 121 years. F-gases are powerful GHGs with a global warming effect up to 23,500 times greater than CO_2. While HFCs are relatively short-lived, PFCs and SF_6 can remain in the atmosphere for thousands of years [30].

With the celebration of the 17th Conference of the Parties to the UNFCCC, the negotiations to adopt a multilateral agreement on climate change advanced. As the evidence of a decreasing path in GHGs emissions inequality could facilitate an international accord to reduce global GHGs concentration[5] and brings the world closer to the state of maximal entropy, in this paper such inequality is analyzed from a multidimensional perspective. In particular, CO_2, CH_4, N_2O and F-gases emissions are studied in the period 1990–2011, using the generalized entropy measures proposed by Maasoumi [32]. In addition, these measures allow analyzing the contribution of the between- and within-group inequality components. Given that countries have different population sizes, it is pertinent to characterize each one by their per-capita emissions, which in thermodynamic terminology are intensive variables. To the best of our knowledge, this is the first attempt to use inequality measures for analyzing, in a joint manner, the global distribution of GHGs emissions. In this sense, we are convinced that the use of quantitative methods for analyzing the historical trend of global inequality in GHGs emissions is a significant step toward solving climate change problem.

The specification of the multidimensional inequality indices applied in this paper [32] is an extension of the one-dimensional generalized entropy indices [33–36] which are based on the concept of entropy of the information theory [37,38]. The generalized entropy indices consider the redundancy or non-randomness — measured as the difference of entropy with respect to the situation of maximum entropy. This concept is also closely related to the Shannon [39] entropy, which comes from the statistical concept of entropy expressed by Boltzmann [40] and Gibbs [41]. In these works, the entropy

[1] Several papers have studied distributional aspects of income in the main world economies [2–4].

[2] Annex A of the Kyoto Protocol [9] stated that the six main GHGs are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).

[3] That is, the emission of 1 million ton of CH_4 is equivalent to emit 28 million tons of CO_2

[4] CO_2 lifetime is not defined because it is not destroyed over time. Some of this gas is absorbed quickly but some will remain in the atmosphere for thousands of years [29].

[5] In addition, a decreasing trend of inequality in natural resources may lead to more social trust [31].