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Analysis

Ecological footprint inequality across countries: The role of environment intensity, income and interaction effects

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ABSTRACT

Recently, White (2007) analysed the international inequalities in *ecological footprints* per capita (EF hereafter) based on a two-factor decomposition of an index from the Atkinson family (Atkinson, 1970). Specifically, this paper evaluated the separate role of environment intensity (EF/GDP) and average income as explanatory factors for these global inequalities. However, in addition to other comments on their appeal, this decomposition suffers from the serious limitation of the omission of the role exerted by probable factorial correlation (York et al., 2005). This paper proposes, by way of an alternative, a decomposition of a conceptually similar index like Theil's (1967) which, in effect, permits clear decomposition in terms of the role of both factors plus an inter-factor correlation, in line with Duro and Padilla (2006). This decomposition might, in turn, be extended to group inequality components (Shorrocks, 1980), an analysis that cannot be conducted in the case of the Atkinson indices. The proposed methodology is implemented empirically with the aim of analysing the international inequalities in EF per capita for the 1980–2007 period and, amongst other results, we find that, indeed, the interactive component explains, to a significant extent, the apparent pattern of stability observed in overall international inequalities.

1. Introduction

The concept of ecological footprint has received a great deal of attention in the literature on the environment. The *ecological footprint* (EF hereafter), introduced by Rees (1992) and developed by Wackernagel and Rees (1996), addresses the use of resources associated with productive and human activities, homogenising it based on the amount of bioproductive land necessary to produce the required resources.[1] In this respect, an interesting analysis would be to examine the international distribution of this indicator as an exercise to compare the level of equality in the use of resources between countries, in a context of limitations on the planet's biocapacity and the accelerated growth in consumption.[2] This analysis, which has already been done by authors such as White (2007) and Dongjing et al. (2010) in an international context,[3] would appear to be more comprehensive than the typical analyses that focus on partial environmental indicators such as CO_2, energy intensities or local pollutants.

In particular, an interesting analysis in the context of an international distributive analysis of this measurement, would be one that evaluates the role of environmental intensity (measured here as EF/GDP and identified as EF intensity hereafter), and level of affluence as explanatory factors of global inequalities in EF, following in the wake of the IPAT model and the Kaya identity (Kaya, 1989). In particular, intensity is seen as an indicator of environmental efficiency, by relating the volume of productive and human activity with the associated need for resources. The lower the intensity, the more decoupled the economy. Thus, refinements in efficiency of production are required to counterbalance the expected growth of population and affluence over this century. Otherwise, the impact will

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[1] The EF has been adopted by a growing number of government authorities, agencies and policy makers as a measure of ecological performance. Noteworthy examples are those international applications such as the European Environment Agency (EEA, 2010), the European Parliament and the European Commission (Best et al., 2008), who consider the EF to be a useful tool for measuring the environmental performance of the EU, or the United Nations Development Programme which considers EF as capturing the environmental dimension of human development (UNDP, 2010).

[2] Any aggregate indicator will have both strengths and weaknesses (for example, measures of aggregate economic output), and this also applies to EF. Especially when it deals with measuring sustainable development (see Bergh and Verbruggen, 1999). However, EF is well suited in this research paper since the issue under investigation is the distribution of resource use and not the sustainability assessment.

[3] Also Wu and Xu (2010), for example, are conducting the analysis for the Chinese provinces. Despite not focusing on EF, worthy of mention are the works of Steinberger et al. (2010), where the authors analysed international inequality of the Domestic Material Consumption indicator and its main components for the year 2000, and also Hedenus and Azar (2005), who not only studied the inequality of Carbon emissions but also the inequality of consumption of paper, energy, electricity, food and animal food for a period of 40 years (1960–2000).

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continue growing (York et al., 2005).[4] Since EF per capita is the product of both affluence and intensity, international inequality in EF per capita is consequently also explained by both factors. In this context, White (2007) suggests decomposing an index such as Atkinson's with an inequality aversion parameter equal to 1 (Atkinson, 1970) in the multiplication of individual factorial indices (hence associated with EF intensity and average income) and a component that covers factorial averages. Hence, amongst other aspects worth noting, this decomposition does not precisely consider the role that might be played by the probable correlation between the two factors, which has already been clearly documented by York et al. (2005). In this way, the factors included in White's (2007) exercise, or one of them, appear as a type of black box that can contain both the partial impacts and the indirect impacts arising from the interactions between them and, consequently, the decomposition seems rather ambiguous.

In view of these circumstances, this paper proposes the usefulness of alternatively decomposing an index such as the Theil index (Theil, 1967), which is cardinally equivalent to the Atkinson index mentioned earlier, which can, indeed, be decomposed (in an additive way, furthermore) in the partial contribution of both factors (intensity and GDP per capita) plus a factorial interaction component. This decomposition can be immediately extended with the aim of analysing the group inequality components (Shorrocks, 1980). This paper also undertakes an empirical illustration of this proposed decomposition in order to analyse the international inequalities in EF per capita during the 1980–2007 period and the group inequality components according to the regionalisation criteria adopted by the IEA (International Energy Agency), which contemplates nine world regions.

This paper is therefore structured as follows: the second section addresses the main methodological elements of the proposed decomposition. The third section presents the main findings obtained after applying this methodology to the analysis of inequalities in EF per capita during the 1980–2007 period. Finally, a section is devoted to summarising the main conclusions drawn from this analysis.

2. Ecological Footprint Inequalities and the Role of Environment Intensities, Income and Interaction Effects: Methodological Aspects

One of the most interesting approaches designed to investigate the explanatory factors behind ecological footprint by country consists of breaking down, by multiplication, their level of intensity in the use of resources and the average income (York et al., 2005):

$$e_i = \frac{E_i}{P_i} = \frac{E_i}{Y_i} \cdot \frac{Y_i}{P_i} = I_i * y_i \tag{1}$$

where E_i is the ecological footprint of country i; P_i is its population and Y_i is its GDP; e_i is the ecological footprint per capita; I_i is the EF intensity factor, and y_i is the GDP per capita.

Thus the use of resources per capita would be broken down in the part associated with intensity of resource use and global economic activity per capita (i.e. the scale effect). In the first case, its importance would be associated with factors such as environmental efficiency.

In this respect, and with the aim of evaluating the inequalities in EF and the role of the two previous multiplicative components,[5] White (2007) used the Atkinson index (Atkinson, 1970), with an inequality aversion parameter equals to 1.[6] Specifically, the aversion parameter used would indicate the presence of a progressive-type inequality index (sensitive to changes in the lower part of the distributive ranking by countries) but not extreme (Atkinson, 1970). To be specific, this index would be expressed as follows (already adapted to the analysis of the ecological footprint per capita in its notation):

$$A(e) = 1 - \Pi_i \left(\frac{e_i}{\mu^e}\right)^{p_i} \tag{2}$$

where μ^e is the global average of e; and p_i is the relative population of country i.

Replacing Eq. (1) by Eq. (2) and manipulating the equation, we find that:

$$1 - A_e = \left(\frac{\mu_i \cdot \mu_y}{\mu_e}\right) \cdot \Pi_i \left(\frac{y_i}{\mu^u}\right)^{p_i} \cdot \Pi_i \left(\frac{I_i}{\mu^I}\right)^{p_i}. \tag{3}$$

And thus White (2007) established that:

$$1 - A_e = \left(\frac{\mu_I \cdot \mu_y}{\mu_e}\right) \cdot \left(1 - A_y\right) \cdot (1 - A_I) \tag{4}$$

where $1 - A_e$ would be an equality index (according to the author); μ_I is the global average of EF intensities and μ_y the average GDP per capita.

However, if we analyse this in detail, it is not difficult to see that the last multiplication of Eq. (3) is not exactly an Atkinson index. Indeed, if it were, the weight vector would have to be consistent with the actual variable analysed, in this case the EF intensity. This is indeed the case for $1 - A_y$, where the weighting in expression (3) comes from population-shares. In the case of $1 - A_I$ the weightings of the differences across countries should, if we are talking about the Atkinson index in the strictest sense, be done based on GDP-shares. This is not a trivial difference. Indeed, it is plausible that, on an empirical level, the value of this pseudo-Atkinson index could reach negative signs, which would indicate that it contains factorial correlation components. In this way, therefore, one of the components detailed in the decomposition, i.e. $1 - A_i$, is not strictly speaking an Atkinson index and, moreover, the factorial correlation is not individualised.

In this respect, it would be interesting to have a decomposition which: firstly, decomposes the global index in a series of strict inequality indices (or partial factorial contributions) for each of the factors; secondly, it would be interesting if the decomposition were to include, separately, the role of the factorial correlation; thirdly, it would be good for the decomposition of inequality to be additive, as

[4] It should be taken into account that a greater efficiency of resources does not necessarily involve greater sustainability since it might be accompanied by an absolute increase of resources. This is the well-known rebound effect. Indeed, several high income countries, despite being more efficient (less intensive in resources), have largest EF per capita. Furthermore, GDP per capita is conventionally used as a measure of society's welfare. However, it only measures the total *monetary* value of goods and services produced within country borders in a given year. It does not take into account nor the depletion of natural resources nor the ecological productions. Indeed, GDP may increase with further use of fossil fuels. In this same line, those defensive expenditures that aim at avoiding or correcting impacts caused by GDP growth, are also positively added in GDP accounts. There are many other dimensions that GDP per capita does not capture properly in order to measure social welfare (such as wealth distribution, domestic work, and quality of goods and services). Therefore, some caution must be taken in interpreting both EF intensity and GDP per capita.

[5] EF can also be broken down into six additive footprints (carbon, cropland, grazing, fishing, forest and build-up). A decomposition of international EF inequality according to such components can be found in Teixido-Figueras and Duro (2012) where data from 1961 to 2007 are used. Main results indicate that the carbon footprint became the most important contribution to EF inequality because of its rising share in total EF rather than its inequality, which actually decreased. In contrast, grazing and fishing footprints (related to the diets of industrialised countries) exhibited relatively high levels of inequality despite contributing modestly to total EF inequality because of its low share of total EF. Finally, Cropland footprint contribution to EF inequality reduced significantly as a result of having both historically low inequality (basic subsistence depends highly on cropland consumption) and having decreased its EF share in the course of the period.

[6] The use of an index from the Atkinson family is slightly surprising, given the objective difficulties in decomposing it in parts (Bourguignon, 1979).